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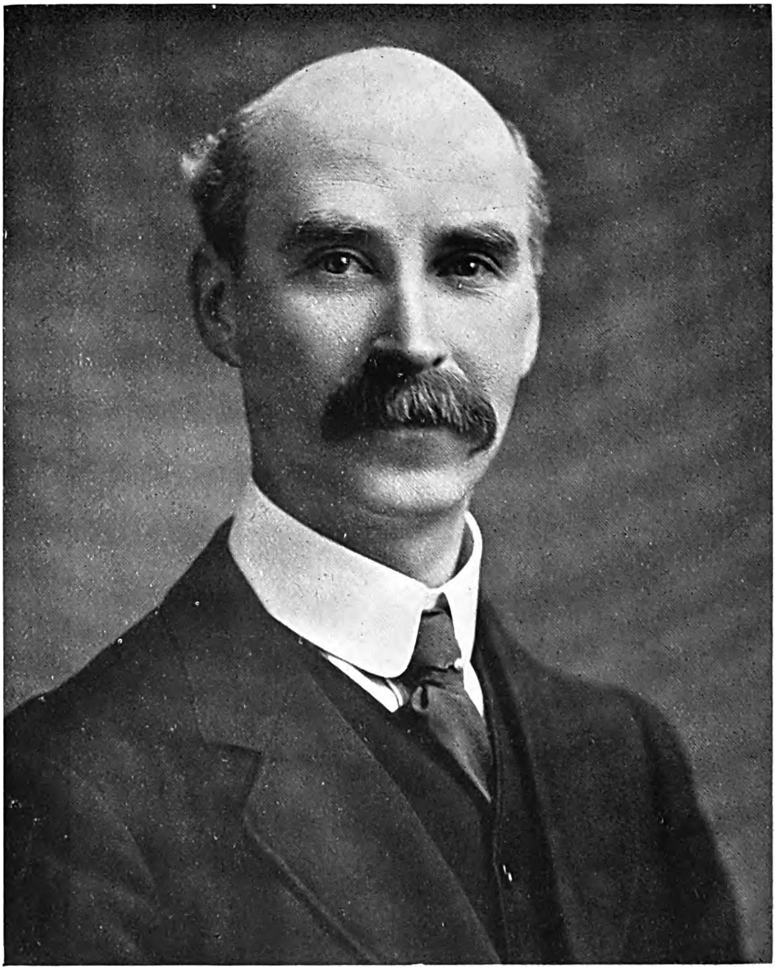

CHARLES R. GIBSON, F.R.S.E.,
President, 1922-1925.

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OF THE

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VOLUME LIII

SESSION 1924-25

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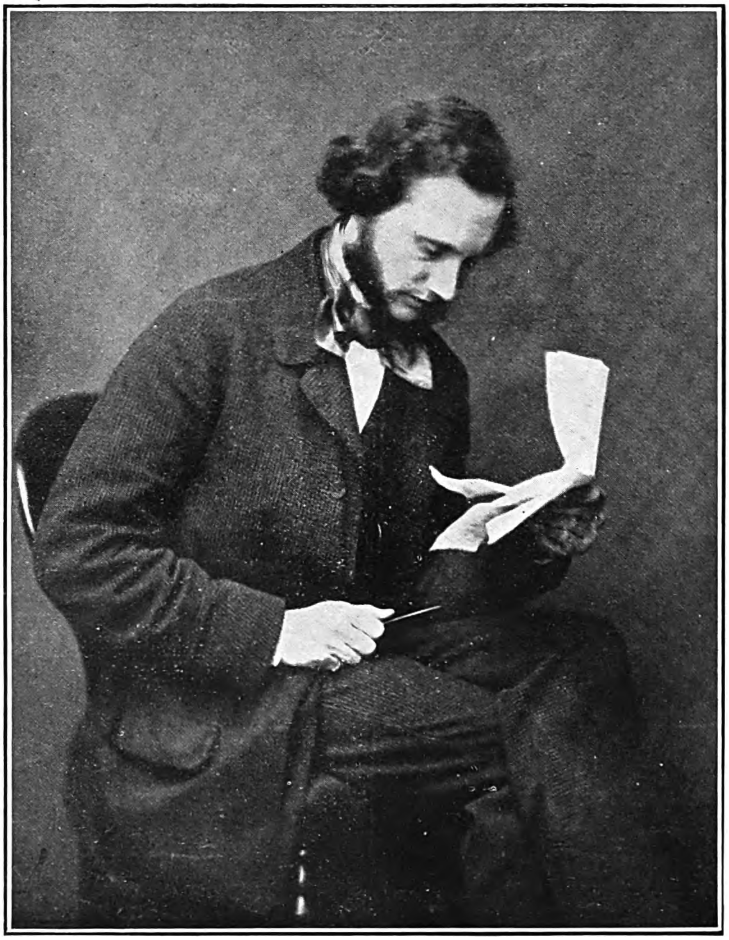

(W Thomson) reading a letter or letters from Fleeming Jenkin, about experiments on sub-marine cables probably about March 1859

K, 24 Hamilton Terrace Ln. Nov 23/92

PROCEEDINGS
OF THE
ROYAL PHILOSOPHICAL SOCIETY OF GLASGOW.

SESSION 1924-1925.

Lord Kelvin: A Centenary Address.

By Sir J. ALFRED EWING, K.C.B., LL.D., F.R.S., Principal and Vice-Chancellor of the University of Edinburgh.

(*Read before the Society, 8th October*, 1924).

A traveller who leaves a cathedral city finds, as he looks back, that with increasing distance the minster towers more and more conspicuously above the common buildings that surround it. Within and among them he had imperfectly grasped its pre-eminence, its distinction, its unity: he had seen it only in parts. His view had been hampered by the environment and by the very vastness of the thing itself. But now, as he goes further off, what had seemed comparable drops into insignificance: the structure reveals itself as a whole. He sees it more justly, more comprehendingly, for what it is.

So is it with the personality and work of Lord Kelvin. A hundred years have passed since he was born; more than eighty years have passed since he began that amazing career of discovery and invention which is without parallel in the history of science. And now, looking back, we can discern with greater clearness the man and his achievements, and trace the influence—potent and far-reaching—which he exercised on the life and thought of his own time and of the time that has followed.

His was a period rich in opportunities for discovery. In 1841, when he began, at the age of 17, to publish original scientific papers, the unexplored regions of thought that awaited the physical enquirer might be compared, in their extent and variety, to the New World of the Elizabethan adventurers. The French mathematicians, Legendre, Lagrange, Laplace, Fresnel, Fourier, following on the great work of Newton, had prepared the way for many advances. The foundations of a science of electricity had been laid by Ampère, and Faraday was pausing to take breath after his first splendid outburst of experimental research. But there were as yet no accepted units in which to state and measure electric and magnetic quantities. There was no science of energy, no knowledge even of the mutual convertibility of heat and work. The laws that govern the establishment of the electric current had still to be formulated. And the field of what we now call applied science, that is to say, the application of scientific principles and scientific methods to produce devices for the use and convenience of man, was as yet almost wholly untilled. Here then was an opening for a man of genius ; nay, a bewildering choice of openings. And if we attempt to review Kelvin's life, we too are bewildered to find him, as it seems, in all, and making history in each.

When your Council did me the honour of inviting this address, they no doubt realised that I am one of the small and rapidly diminishing band of those who not only knew Kelvin in his prime and came under his inspiration, but were privileged to assist him in some portions of his work. It was in 1872 that I first knew him in the relation of a master. He was still in his forties, at the crest, one may say, of his powers, pulled hither and thither by multifarious claims on his attention, intensely active in body as in mind, unresting, untiring, successful in a host of undertakings, revered as a leader in the learned world of science, famous with the crowd for his practical achievements, especially for the inventions that had made Atlantic telegraphy possible. To a student whose love was divided between physics and engineering no happier fate could be imagined than to become associated with Sir William Thomson. Among many good things I had learnt as a pupil of Tait was to reverence the genius of

Thomson. And the esteem thus awakened before I came to know him found nothing to check or temper it as a result of personal contact and fuller knowledge. On the contrary, my devotion to him grew stronger through several years of service and many years of friendship, until the day, when, in the gloom of Westminster Abbey, I followed his body to its last resting-place beside the grave of Newton. As time went on my reverence became more and more mingled with warm affection for one who was among the kindest, most modest, most lovable of men.

Memories come up of mornings in his study or in the laboratory, of evenings in the genial home circle. I recall the benevolent bending of the eyes from under the brooding forehead, the quick, lame step*, the searching questions that went straight to the heart of the matter, the suggestive comment, the generous appreciation. I recall frequent visits to James White's shop in Sauchiehall Street, where, passing at once into the little workshop behind, he would give his directions to the instrument-maker and scribble on a torn envelope the only "working-drawing" that in those days ever guided the birth of his inventions. Or, again, the fits of abstraction, when, pulling out of his pocket the green quarto note-book that was always there, he would bury himself in some calculation, oblivious, as it appeared, of what was going on around, neglectful even of his favourite parrot's repeated invitations to join in the whistling of a part song. It was that observant bird which was so often driven to exclaim, in accents of well-merited reproach : "Late again, Sir William." In those days Sir William Thomson and Professor Fleeming Jenkin were partners in consulting work relating to submarine telegraphs. Jenkin, whose pupil I had been, asked me to serve as one of the assistants of the firm. Part of the work was done at the factory in London, where a new cable was being made, and where we of the staff had to watch its behaviour from day to day by making systematic tests, and part was done at sea, when one or another section of cable was being laid. It was on one of these cable-

* The bone of his left thigh had been broken by a fall on the ice when he was 36, and the leg was permanently shortened.

laying expeditions that the Knight, as we called him (knights were less common then than now), found his Lady—an event which brought enduring happiness. Sir William was at that time an ardent advocate of the art of signalling by the Morse alphabet, using long and short occultations of a lamp. While the cable-ship "Hooper," which carried him on its first voyage, lay in the harbour of Funchal, Madeira, he met Miss Blandy, daughter of a leading man in the Island, and discovered with surprise and delight her quickness in learning Morse and reading messages from the ship to her father's house. Next year he returned to Madeira in his yacht, and, Viking-like, won her and brought her home as his bride.

It was in such expeditions as well as through his fondness for yachting that he acquired the intimate practical knowledge of navigation which led him to many inventions in that art. In this connection may I repeat a little story that has been told before. He insistently preached the truth that when a navigator takes a "sight" of the sun, what he learns is that the ship is somewhere on a certain line, and the proper way of working out any sight should include the drawing of a sufficient portion of this line, which is called a position line. To facilitate finding the line Thomson invented a new method of calculation by the aid of Tables, which we used in cable-laying voyages, and in the publication of which I subsequently helped. The published Tables received favourable notice in "Nature," but were afterwards attacked in that journal by the Astronomer Royal, Sir George Airy, then a very old man who might without injustice be described as opinionated. The attack was based on a misunderstanding by Airy and was wholly invalid. I was indignant, and sent a message to Sir William, asking whether I might publish a reply. He telegraphed: "Yes, by all means answer in your own name, but don't hit too hard. Remember he is four times as old as you." The spirit of the injunction was characteristically kind, and I daresay a warning was not unnecessary.

In those days the testing-room of the cable factory was a better school of electrical measurement than could be found in any laboratory. We had the daily handling of instruments of previously

unmatched precision that had been created to meet the necessities of the industry. I well remember how, when Thomson periodically visited London to inspect the progress of the work, one of us would meet him at Euston to accompany him in the cab, telling him results of the tests, and receiving instructions, so that none of his precious minutes should be lost. Later, when I was working mainly in Edinburgh with Fleeming Jenkin, Thomson's visits from Glasgow were thrilling events. He was then President of the Royal Society of Edinburgh, a lively central figure in it and author of many communications. One listened to these with wholehearted enjoyment and partial understanding. After the meetings he would occasionally take me on to the Evening Club, where I would sit silently receptive, while he and Tait and Crum Brown and other giants smoked churchwarden pipes and talked. Except for such placid moments my memories of those visits are memories of hurry and distraction. For Thomson had not only the affairs of the Society to take up his attention : there were other claims on his crowded hours, two claims especially that could not fail to come into sharp rivalry. Besides being Jenkin's partner in practical concerns which involved big responsibilities and quick decisions, he was also Tait's partner in the authorship of Thomson and Tait's Natural Philosophy. So between Jenkin and Tait there was, one may say, a sort of strife for Thomson's soul. I am afraid that in Tait's eyes Jenkin stood for a malign influence, dragging Thomson to earth when he should have been free to soar into regions where the natural philosopher might forget that he had any concern with the lives of men.

That, however, was never Thomson's opinion. He brought his supreme gifts of imagination, of energy, of assiduity, of patience, to the service of practical invention as willingly and as effectively as he brought them to the service of pure theory. Let me quote his own words :*

" There cannot be a greater mistake than that of looking superciliously upon practical applications of science. The life and soul of science is its practical application, and just as the great advances in

* Popular Lectures and Addresses I., page 86.

mathematics have been made through the desire of discovering the solutions of problems which were of a highly practical kind in mathematical science, so in physical science many of the greatest advances that have been made from the beginning of the world to the present time have been made in the earnest desire to turn the knowledge of the properties of matter to some purpose useful to mankind."

He is speaking here of what may be called the beneficent reaction of practice on science, a thing some scientific workers are apt to underestimate or overlook. He quotes by way of example the stimulus which was given to the study of electricity and its exact measurement, first by the requirements of submarine telegraphy, and later by the application of electricity to lighting and the distribution of power. In all that he was himself a leader ; and as I shall presently point out, the whole broad theory of thermodynamics and energetics, which owes more to him than to any other philosopher, originated in an earlier effort by Carnot to understand and improve the action of engines in producing motive power by the agency of heat.

Kelvin's practical inventions were, in every instance, the direct outcome of scientific thought. He would be confronted by a new problem, such as that of observing the signals which were to come through a long cable. First the character which the electric impulses might be expected to possess, when they should arrive, had to be investigated mathematically ; then came the dynamical problem of designing an instrument that would respond to them ; and the mirror galvanometer with the very small inertia of its moving system was the result. Later came the problem of recording, to give greater security against error and also greater speed. Here a frictionless method of tracing a record of the deflections had to be devised, a record that would exhibit as a continuous curve all the fluctuations in the received current. This was solved by the invention of the vibrating siphon pen ; but to move that, light as it was, required a reconsideration of the dynamics of the system and an inversion of the coil and the magnet, making the magnet the stationary body and the coil the moving one. Thus was evolved the siphon recorder, by no lucky guess-work, be it observed, but by the deliberate application

of scientific reasoning to determine the function and form of every element in the design.

Or he would take an ancient appliance, such as the mariner's compass, where casual evolution had already for centuries been doing its clumsy and imperfect work. Thomson applied to the compass the methods of rigorous scientific criticism, and then gave to every part such a quality of theoretical fitness as had been lacking before. The result was a new birth, an instrument incomparably more precise, more purposeful, more practically right, than anything the navigator had known. Or, again, he took the still more ancient operation of sounding and revolutionized it by the simple application of a little scientific thought. Every one of the long line of electrometers, current-balances, and other measuring instruments with which he met the requirements of the electrical engineer, no less than his apparatus for the analysis and the synthesis of tides, was the product of a highly trained as well as a highly imaginative and deeply penetrating scientific intelligence. And it should not be forgotten that he was the leading spirit of that band of scientific workers who, stimulated by their realization of practical needs that were just beginning to be felt, not only conceived but gave reality to what is now the accepted system—all the world over—of electrical units.

These practical services to humanity, and incidentally to science, would by themselves give him an enduring title to fame. But those who are familiar with his contributions to scientific theory find there even stronger reasons for placing him among the immortals. Especially is this true of the marvellous output of his earlier years, when he was laying the foundations of thermodynamics, and was establishing at breathless speed the consequences of the new ideas about energy. That was before his interest had begun to be claimed by the problems of the submarine telegraph. I do not mean that there was then, or even later, any pause or stoppage of scientific productiveness. All through his long life, up to his death at the age of 83, his mind continued active, avid of knowledge, independent, creative. His industry never flagged. No year passed without many additions to the list of original papers, which, in the excellent biblio-

graphy that Silvanus Thompson has appended to his *Life of Lord Kelvin*, numbers 661. There was much that was great in the product of the middle and the later years; but if we would seek the very greatest, the most enduring, the most foundational, we find it in the discoveries which he made before he was thirty. Nevertheless, the sustained energy, the continued productiveness, the variety, the volume, the persistently high quality of the output, are astonishing, and they are the more remarkable when we reflect that the young Thomson was remarkably precocious. He was never sent to school. At the hands of his father (his mother had died when the boy was six years old) William received a Spartan but intensely loving and stimulating home-training, in company with his brother James, who was two-and-a-half years older, and with sisters, one of whom, Elizabeth, was some three years older still. Under the title "Lord Kelvin's Early Home" she has drawn a charming and vivid picture of the devoted father and the receptive children, first in the household in Belfast, and later in the Old College in Glasgow where, when William was eight years old, his father was appointed Professor of Mathematics. She tells how the father gathered about him the motherless children—seven in all—and watched over them continually. "William," she says, "was a great pet with him, partly perhaps on account of his extreme beauty, partly on account of his wonderful quickness of apprehension. . . . . He was, however, easily irritated if he were crossed, and then he became snappish a little and we would say: 'Willie's in the crabbs, don't mind him.' And it was the best way; and if he was let alone the crabbs vanished and sunshine quickly returned." William was scarcely four when he learnt from his father what was then called "the use of the globes." As an old man he declared humourously that he was a conscientious objector against paying for any education that did not include the use of the globes. The elder brother, James, who in time became an engineer of high repute and succeeded Rankine as Professor of Engineering in the University, was, even in those early days, somewhat eclipsed by his younger brother, whose superb health and buoyant energy James unfortunately did not share. James Thomson was a man of exceptional originality and independence of thought, to

whom we owe several notable discoveries and inventions. In more than one instance, his suggestions afforded a foundation on which the quicker and more comprehensive brain of William proceeded to build. Between the brothers there was much affectionate intercourse and scientific communion : in later life it was beautiful and even touching to see William's deference to his brother's opinion, his eagerness to bring James forward and have his genius (for it *was* genius) properly recognised. And it was also, sometimes, difficult not to be impatient ; for James, great as was his insight, seemed wanting in some sort of mental perspective, and had very little sense of time. There was never a flaw in his logic ; it was devastatingly thorough and would tolerate no admission of even the most obvious preliminaries, Occasionally one listened to his argument as the wedding guest listened to the tale of the ancient mariner, wondering not so much when it would end as when it would really begin. I remember his once holding me, at a delightful evening party in his own house, while he discoursed upon the dynamical consequences which were being produced on the earth's rotation and the position of its axis in space, by the motion of the couples who were then gyrating in his drawing-room. It was no doubt an interesting problem, but I was at an age when there was more enjoyment to be got by taking part in the operation than by listening to a discussion of its cosmical effects.

When, together, the boys began to attend classes in the University, William, though the junior and only ten years old at the time he matriculated, usually carried off the first prize, the second prize falling to James. At the age of fifteen, William, besides gaining the first prize for Astronomy, was awarded a University Medal for an Essay on The Figure of the Earth. He has told how, on the very day the prizes were given, the 1st of May, 1840, he took Fourier's *Théorie analytique de la Chaleur* out of the University Library : "and in a fortnight (he adds) I had mastered it—gone right through it."

This reading of Fourier was one of his spiritual milestones ; its influence was enormous on the subsequent direction of his thoughts. Going that summer with his father and the rest of the family to Frankfort, where the intention was that they should learn German

he took Fourier, and with it a book by Kelland on *The Theory of Heat*, which greatly shocked him by saying that Fourier's analysis was mostly wrong. His sister tells how one day he suddenly sprang up exclaiming : "Papa ! Fourier is right and Kelland is wrong ! " So indeed it was, and accordingly the earliest of Thomson's published papers, written when he was just sixteen, is a conclusive defence of the analytical methods of Fourier. It now forms the first item in Volume 1 of his collected works. It is pleasing to know that Kelland, though momentarily piqued, bore no malice toward the gifted boy, and soon afterwards helped him with an introduction to mathematical colleagues in France.

In 1841 William Thomson entered Peterhouse to work for the mathematical tripos. As an undergraduate he continued to produce and publish original papers in mathematical physics, one of which, written while he was still seventeen, traces an exact mathematical correspondence between electrostatic induction through a dielectric medium and thermal flow through a conductor of heat. As Sir Joseph Larmor says, it is remarkable that a youth of seventeen should have discovered such an analogy between electric force and thermal flux " fundamentally illuminating to both, and pregnant with the great advances then impending in physical science."*

Before Thomson took his degree he had the beginnings of a European reputation ; he was already looked on as a coming light in the world of mathematics. " It is hardly wonderful (again I quote Larmor†) that the result of all this scientific activity of the highest order was that in the Mathematical Tripos at the beginning of 1845 he only attained to the second place in the list." To work rapidly for the purpose of an examination requires talent of a different type. One of the examiners has recorded that his colleague, speaking to him of Thomson, said : " You and I are just about fit to mend his pens." But a few days later Thomson was adjudged winner of the Smith's Prize, which has always been regarded as a higher test of original power.

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* Proc. Roy. Soc. Vol. 81. Obituary Notice of Lord Kelvin, page ix.
† Ibid. Page viii.

A man of his aboundlng vitality was not likely to neglect other sides of undergraduate life. In his second year he rowed with good effect in his College boat, helping to keep it from being bumped by Caius. "We had a glorious pull for it," he says in his diary, "and I shall remember for my whole life the work of seven minutes last night. My pleasure at keeping away was beyond anything I have ever felt." Years afterwards he told the story thus: "Caius never got near the Peterhouse boat. During those three weeks of the races nothing occurring on the whole earth seemed of the slightest importance. We could talk and think of nothing else. It was three weeks clean cut out of my time for working in Cambridge; so I determined to do no more rowing." Nevertheless he kept up the habit of sculling as a means of exercise, and six months later he won the Colquhoun Sculls almost without training. A keen lover of music, he became President of the University Musical Society, and himself took a part in the orchestra as "second horn." Practising the cornopean served, as the diary records: "to relieve my head from the seediness concomitant upon little-go subjects."

The Cambridge of those days could teach him nothing of experimental physics. The Tripos over, he went off to Paris, met some of the mathematicians who already knew his work, and was introduced by Biot to Regnault, who was then engaged on his famous investigation of the properties of steam and other gases. For a short time he assisted Regnault in these experiments, an experience that taught him much, and before he left Paris another event happened of even greater moment in determining the bent of his mind. This was his making acquaintance with a paper by Clapeyron on the motive power of heat, written some ten years before, in which an account was given of the earlier work of Sadi Carnot. Carnot's wonderful and epoch-making booklet *Réflexions sur la Puissance motrice du Feu* had, in fact, been published in 1824, the very year of Thomson's birth. But, except for the account given by Clapeyron, no memory of it seemed to survive, certainly no realization of its significance as a new departure in science. To Thomson it came as a revelation, though seen only through the medium of Clapeyron's abstract. He searched in vain

for a copy of the book itself; booksellers would offer a volume on some social question by Hippolyte Carnot, the brother, or a treatise on fortification by the father, "the organizer of victory," but the immortal work of Sadi was buried and unknown. Three years later he obtained a copy, and wrote an account of Carnot's theory for the Royal Society of Edinburgh. Before that, even, he had made it the basis of a suggested absolute scale of temperature, which he first published before this Society on 12th April, 1848. The ideas of Carnot were, in fact, the starting point from which Thomson proceeded to develop the principles of thermodynamics.

Meanwhile Thomson, at the age of only twenty-two, had been elected Professor of Natural Philosophy in the University of Glasgow, to the great joy of his father who had hoped and worked for the event. Never was a bold appointment more amply justified. To the ordinary student he was, it must be owned, a poor expositor: his brain was too constantly creative, his thoughts too quick and crowded for effective utterance. He would be tempted down attractive byways when he should have followed the straight road of systematic presentation. The teacher was sometimes lost in the discoverer; his mind would stray to glean sheaves of new knowledge at moments when it should have been concerned only to provide digestible bread from the corn already in store. His meticulous exactness would hedge a statement round with restrictions and qualifications that made it quite unintelligible to persons who had as yet no idea of the simple central fact. Such instruction could be taken in, as certain devils could be driven out, only by prayer and fasting. But for those students who had the will and power to make the necessary effort, there was a rich reward. To them he was a compelling force, a fount of inspiration, a tantalizing delight. And to the University he became more and more an asset and a glory while the years of his professorship—fifty-three in all—rolled on, and his fame spread, as one may literally say, from sea to sea and from the River Kelvin to the ends of the earth. No notice of him as a teacher should omit to mention one monumental service: he invented the physical laboratory as an instrument in University education. There had been nothing of the kind anywhere, until, on

coming to Glasgow, he appropriated a disused room in the Old College, and set a band of students to begin those experimental enquiries into the properties of matter that were to play a large part in the work of his life and in the history of science.

There was another characteristic that affected Kelvin both as teacher and investigator: he did not care to spend time in keeping himself informed of other men's published work. As a youth, indeed, he had absorbed with enthusiastic interest the writings of Carnot and of Fourier, and had made them a big part of his mental furniture. But such study was by no means the habit of his more mature life: he seemed rather to follow the dictum of the philosopher who declared that a man ought to get his reading over before he was twenty-five. If this prejudiced his teaching, as it doubtless did, there may have been some compensation in the freedom which it left him to obey the impulse of his own originality in research, unhampered by the restricting consciousness of other explorers' tracks. That may well have been an advantage in the early and middle periods of great productivity: in later life it was, I think, a drawback, for it kept him from a full comprehension of advances which by that time were changing the whole aspect of physics. But though he was a poor absorber of the printed page, nothing could exceed his interest when he visited another worker's laboratory, and saw for himself whatever experiments were in progress. Then his appreciation was quick, he would utter boyish exclamations of delight and could scarcely tear himself away. His unaffected pleasure was the highest encouragement that anyone could wish to receive. When I was Professor of Applied Mechanics at Cambridge, he and Lady Kelvin often came to the laboratory. The visits were apt to lengthen out in a flattering and most enjoyable manner, while his patient companion would gently remind him of some engagement: "You know, William, we *promised* not to be late for lunch."

In the first year of his professorship he became a member of this Society and began the habit of bringing before it matters in which he was specially interested. A list of his many communications has already appeared in your *Proceedings*,* and the Secretary has been so

* "Lord Kelvin," by Prof. Magnus McLean, Proceedings of 11th March, 1908.

kind as to revise it for my guidance. He was first elected to the Presidency at the age of 32. For us, here and now, it is particularly interesting to note that among his early communications to this Society there are three which deal with what I would venture to describe as the most profound and far-reaching of all Kelvin's discoveries, and in all three cases it was here that the earliest publication was made. I mean the paper of 12th April, 1848, "On an Absolute Thermometric Scale, founded on Carnot's Theory of the Motive Power of Heat," and two papers of 19th January, 1853, one "On the Mechanical Values of Distributions of Electricity, Magnetism, and Galvanism," and the other "On Transient Electric Currents." Let me, very briefly, attempt to indicate why, among all the mass of their author's achievement, these items may fittingly be singled out for special comment.

For that purpose I must take you back to Carnot's theory of 1824. Carnot had shown that in any heat-engine the working substance was to be thought of as going through a cycle of operations of such a kind that in one part of the cycle the substance took in heat at a high temperature; and in another part of the cycle it rejected heat at a lower temperature. Then he proved by a simple and perfectly general argument that, for a given supply of heat, and a given range between the hot and cold extremes, the greatest possible amount of work would be obtained if the engine worked in a reversible manner. On that criterion alone depended the mechanical output, and not on any property of the substance, so that all reversible engines working between the same limits of temperature would give the same mechanical return for the heat with which they were supplied. He supposed, in accordance with the views of his time, that heat was a queer kind of fluid, called caloric, which simply passed down through the engine, without loss, from the hot to the cold end, much as water passes from a high level to a lower one by the turning of a water-wheel. But that error in no way affected the validity of his argument nor the truth of his conclusion.

Thomson, meditating on this, saw that Carnot's conclusion led to a means of defining temperature in a manner which would be

absolute, in the sense of being independent of the properties of any particular substance. When you measure temperature by the expansion of a substance, such as mercury, you get an arbitrary scale, depending on what substance you select. But take, instead, a reversible heat-engine ; you will get more mechanical output, or less, according as the interval between the hot end and the cold is big or small. And the output will, as Carnot proved, be quite independent of what substance is used in the engine. Here then, said Thomson, is a possible basis for a temperature scale that will be truly absolute. The idea was as novel as it was brilliant ; it provided the essential scaffolding, or rather the framework, about which the structure of thermodynamics was shortly after to arise.

For Thomson it was but a beginning. At first he was hampered by the error of Carnot, an error which he shared, imagining that the " caloric " passed down through the engine without loss. He did not understand that some of the heat disappears in the process of passing down—that there is an actual conversion of heat into work. Though he had met Joule in 1847, and had heard from him the doctrine of the equivalence of heat and work, he could not at first accept it, being obsessed by the truth, derived from Carnot, that the value of any quantity of heat for the production of work, depends not simply on the amount of the heat but on the range of temperature through which it may fall. It is a strange episode in the history of science, a curious proof of the fallibility of even the most acute minds, that three years passed before Thomson resolved his perplexities and came to see that the principle of Carnot was, after all, entirely compatible with the discovery of Joule—that indeed it was only by combining both that a complete theory could be framed. The same conclusion, one ought to add, was independently reached almost at the same time by Clausius. This was at the end of 1850, and from then onwards Thomson pressed forward at an amazing pace, applying the new ideas to one group after another of physical phenomena, and showing that the first and second Laws of thermodynamics, taken together, formed a master-key to unlock every door. If you have followed this hasty account, you will observe the curious point that,

in the sequence of Thomson's ideas, it was the Second Law that first entered his mind and filled it so completely that the First Law had a long struggle for admission. The original suggestion of a thermodynamic scale, which he had made to this Society in 1848, was affected in detail by the "caloric" error; but when subsequently he rid himself of that he corrected it into the form with which students are now familiar, making the absolute measure of the two temperatures between which any reversible engine works simply proportional to the quantities of heat received at one and rejected at the other.

The absolute scale, as we know it now, coincides with the scale which would be found if we could observe the expansion of an imaginary perfect gas. It is part of the history of the subject that Thomson and Joule carried out together a long series of experiments which established the relation of the absolute scale to the scales that are given by the expansion of real gases, such as air.

Thomson's absolute scale has escaped the rude shocks which, in recent years, have assailed so much that was held for established in physics. There are few other ideas that have not been honeycombed by relativity, but the thermodynamic scale of temperature remains as absolute as its name.

Once it was established, and the results of Joule and Carnot completely reconciled, Thomson, after settling on a sound basis the theory of the production of motive power by the agency of heat, went on to give the principle of the reversible cycle many fruitful and unexpected applications in other fields. In thermoelectricity it led him to discover a reversible convection of heat which is now known as the Thomson Effect. In the theory of electrolysis he used it to infer the electromotive force of a galvanic cell from the known energy of the chemical action. His next step in formulating the general science of energetics was to discuss the "mechanical values," or, as we should now say, the potential energy of distributions of electricity and magnetism, showing how to express mathematically the energy of a charged conductor, of a magnetic field, and of a magnetised substance, and the energy that an electric current stores by setting up a magnetic field, which exhibits itself in the quasi-inertia of self-

induction. This was the subject of one of the two papers which he communicated to this Society in January, 1853. The other, " On Transient Electric Currents" (with its mathematical supplement in the Philosophical Magazine, a few months later), showed how, at every instant in the process of discharging a conductor, the strength of the current might be deduced by applying the equation of energy, and how it followed that the discharge would be oscillatory, provided the resistance fell short of a certain limit depending on the self-induction and the capacity. The paper shows how to calculate the period of the oscillations and the rate at which they subside. Thomson remarks that the theory explains the oscillatory character noted in flashes of lightning, and later (in December, 1859) he had the satisfaction of showing to the Society photographs taken by Mr. Feddersen which demonstrated such oscillations in a laboratory experiment. This investigation of transient currents was the first step towards wireless telegraphy ; though it was left to Clerk Maxwell to recognise, years afterwards, that Thomson's equation omitted one term, namely the energy of the electromagnetic waves which, as a consequence of the oscillation, are radiated into space.

Time does not permit of more than the briefest reference to another paper, which he read before this Society in 1852, " On the Economy of the Heating or Cooling of Buildings by Means of Currents of Air." It suggests a process in which a heat-engine is worked backwards to produce cold. This was given effect to many years after by Mr. Coleman in the well-known Bell-Coleman refrigerating machine. And the paper makes a further suggestion, strikingly true but never yet practically applied, that in the heating of buildings it is wasteful to make direct use of the high temperature heat of burning fuel : that the heat of a furnace might, with far greater thermodynamic economy, be used to drive an engine which should pump up heat from the atmosphere or the ocean to the moderate level of temperature at which it is wanted. His very first communication to the Society, in April, 1847, was an account of Stirling's Air-Engine, which appealed to him as a means of realising the cycle of Carnot. He points out its advantage over the steam-engine in having a bigger temperature-

range, and also that when driven reversed it will produce a refrigerating effect.

These things, and many more, came from Thomson's study of Carnot; and it is to the same source that we owe his profound, wide generalisation—also published in 1852—that there is, in nature, a universal tendency to the dissipation of mechanical energy. Briefly put, this means that any material system, however extensive, is in the condition of a wound-up clock which is slowly but surely running down. Not that the energy of the system gets destroyed, but only that it gradually loses its availability for transformation. The processes that are going on include irreversible features, and so the energy of the system drifts towards a final state of uniformly diffused heat. And he draws the cosmical conclusion: "Within a finite period of time past, the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted, unless operations have been, or are to be performed, which are impossible under the laws to which the known operations going on at present in the material world are subject."

From this it was a natural step to express his revolt against the doctrines of the uniformitarian school in geology which seemed to demand unlimited aeons for the operations of geological history. By various lines of argument he attempted to fix limits to the age of the earth, thereby provoking a controversy into which there is no need now to enter. The later discoveries of radioactivity, which show that within some of the atoms of matter there is a source of energy, then undreamt of, substantial enough to affect the calculation, have altered the numerical estimates; but the main contention holds. It did a lasting benefit in rousing geologists and biologists from what Sir Archibald Geikie has called their "comfortable belief in the limitless ages of the past."

I have said nothing of Kelvin's lifelong efforts to solve the mystery of the atom. I once heard him remark that from the day when he conceived the idea that the atom might owe its indestructibility to being a closed vortex in a frictionless fluid, he felt that any

time given to other subjects was relatively wasted. Later, however, he was driven to abandon that fascinating hypothesis. He was the first to estimate the size of the atom, and he lived long enough to see the subject of atomic physics enter on a new, progressive, bewildering phase. There is a note of sadness no less than of humility in the words he used on the occasion of his jubilee (1896), when all the world was doing him homage :—

"One word characterizes the most strenuous of the efforts for the advancement of science that I have made perseveringly during fifty-five years : that word is *failure*. I know no more of electric and magnetic force, or of the relation between ether, electricity, and ponderable matter, or of chemical affinity, than I knew and tried to teach my students of natural philosophy fifty years ago in my first session as professor."

Yet it may be doubted if there has ever lived a happier man. To him work was a passion rather than a duty ; he had the constant joy of intellectual adventure, the frequent satisfaction of completed achievement. He had the love of all about him ; he found and kept a place in life that gave his powers the finest, the most unrestricted scope. He was unspoilt by success.

I will only add that he held to a simple christian faith, caring deeply for essentials but indifferent to matters of dogma or of form. His faith, it seemed, was strengthened rather than weakened by his study of science. If his pondering over energy and its inevitable dissipation led him to conclude that any material system works slowly towards an end, it equally compelled him to look back and discern a beginning in what must primarily have been a creative act. From creation it was easy to infer purpose, design, destiny, God. His conviction was that of the poet in the familiar lines :—

"Our little systems have their day ;
They have their day and cease to be :
They are but broken lights of Thee,
And Thou, O Lord, art more than they."

For the student of Lord Kelvin's life and work much matter is available. There is the collection in six volumes of his *Mathematical and Physical Papers*, published by the Cambridge University Press; the earlier collection in one volume of his *Papers on Electrostatics and Magnetism* (Macmillan); the volume of his *Baltimore Lectures*, dealing mainly with molecular dynamics and the wave theory of light; and a set of three volumes of *Popular Lectures and Addresses*. There is also, of course, Thomson and Tait's *Natural Philosophy*, in the writing of which he took a large share. Then there is the careful and comprehensive *Life*, in two volumes, by the late Professor Silvanus Thompson; and the account—already mentioned—of *Lord Kelvin's Early Home*, by his sister, Mrs. King—(these were both published by Macmillan in 1910). Reference should also be made to the Jubilee volume published by MacLehose in 1899, containing a narrative of the celebration and an admirable essay on Lord Kelvin by the late Professor G. F. Fitzgerald; to the Obituary Notice in the *Proceedings of the Royal Society* for 1908, in which Sir Joseph Larmor gives a deeply interesting summary and analysis of much of Kelvin's greatest work; to the volume on *Lord Kelvin* in the *English Men of Science* series (Dent), written with the advantage of intimate personal knowledge by his successor, Professor Andrew Gray; and to the series of annual *Kelvin Lectures* delivered before the Institution of Electrical Engineers. Up to the present date fifteen of these lectures have been given. In nearly all cases the lecturer has selected for treatment some particular aspect of Kelvin's activity, and the list, which is appended, gives evidence of the variety of subjects which owe their development in great part to his initiative:—

1908—First Lecture: Prof. S. P. Thompson—"The Life and Work of Lord Kelvin."

1910—Second Lecture: Prof. J. A. Ewing—"The Work of Lord Kelvin in Telegraphy and Navigation."

1912—Third Lecture: Prof. H. du Bois—"The Work of Lord Kelvin in Electricity and Magnetism."

1913—Fourth Lecture: Dr. R. T. Glazebrook—"The Ohm, the Ampere and the Volt. A Memory of Fifty Years, 1862-1912."

1914—Fifth Lecture : Sir Oliver Lodge—" The Electrification of the Atmosphere, Natural and Artificial."

1915—Sixth Lecture : Prof. Andrew Gray—" Lord Kelvin's Work on Gyrostatics."

1916—Seventh Lecture : Dr. C. Chree—" Lord Kelvin and Terrestrial Magnetism."

1916—Eighth Lecture : Dr. A. Russell—" Some Aspects of Lord Kelvin's Life."

1918—Ninth Lecture : Prof. M. Maclean—" Lord Kelvin as a Teacher."

1918—Tenth Lecture : L. B. Atkinson—" The Dynamical Theory of Electrical Engines."

1920—Eleventh Lecture : Dr. C. V. Drysdale—" Modern Marine Problems."

1921—Twelfth Lecture : Sir William Bragg—" Electrons."

1922—Thirteenth Lecture : Sir Ernest Rutherford—" Electricity and Matter."

1923—Fourteenth Lecture : Dr. J. A. Fleming—" Problems in Telephony, Solved and Unsolved."

1924—Fifteenth Lecture : G. Semenza—" Kelvin and the Economics of the Generation and Distribution of Electrical Energy."

The accompanying photograph is reproduced with the kind permission of Lord Kelvin's niece, Miss Agnes Gardner King. It dates from 1859, and shows him absorbed in reading a letter from Fleeming Jenkin, whose association with him in devices relating to submarine telegraphy had then just begun.

Roads and Road Transport.

By Lord MONTAGU OF BEAULIEU, K.C.I.E., C.S.I., C.I.M.E., A.I.C.E., M.Inst. Transport.

(*Read before the Society, 20th November,* 1924).

It is not till recent years that roads and road transport have received the share of public attention which they merit. Twenty-five years ago, up to the time when the motor-car first became a vehicle entitled to a speed of over 4 miles an hour, by the Act of 1896, our only idea of long distance transport was by means of rails, or by coastal shipping. Up to that date the roads were regarded merely as a means for local transport between adjacent towns or villages, and the idea of going by road for even so comparatively short a distance as from Glasgow to Edinburgh, much less Glasgow to London, did not exist. Going a little further back we find, of course, a different state of affairs. Up to 1830 or possibly even up to five years later, long distance mail and stage coaches were running in large numbers with comparative punctuality, and considering the difficulties they had to contend with, made excellent speeds. An average of ten miles an hour, if deductions are made for the loss of time necessitated by the changing of horses, and by stiff adverse gradients, is no mean performance with horse-flesh over long distances. But in the intervening 65 years, between 1835 and 1900, during which most of us in this room were born, we were brought up to think of long distance travelling in terms of railways and railways alone, and for us any consideration of the road and of its value politically, socially and economically, did not exist. I remember myself on one of my earliest journeys on the main road between London and Southampton, in the year 1898-9, seeing grass growing between the horse and wheel tracks on a somewhat deserted piece of this great

highway near Winchester. Nowadays this same road, which runs parallel to the main line of the Southern Railway, between Southampton and London, probably bears along its surface more passengers and a greater tonnage of goods than the railway itself in the course of any year. Everywhere we look in the last 25 years the volume of road traffic has increased prodigiously. Indeed, to-day, road transport is more important from every point of view than rail transport. Moreover, it is interesting to reflect that were the railways of this country to cease operating owing to some cause, civilised life would still be possible and be little affected because we possess road transport. In many cases, except for certain heavy trades, commerce could proceed as before, though it might take a short time before certain industries could accommodate themselves to the new state of affairs. But, on the other hand, were road transport to be suspended, and all mechanical road transport vehicles cease to run, within twenty-four hours the greater part of the population would be starving, and Government, local and central, would be embarrassed and nearly all commerce would cease.

Again I would draw your attention to the fact that while railways have been in existence about 100 years—the Stockton-Darlington railway was opened in 1825—roads and road transport as we know them to-day have only existed for 25 years, and during six years at least of these 25 years, very little progress was possible either on the road or with the vehicle, for the Great War absorbed the energies of the nation and of most of its citizens. Moreover, it was not till 1904 that commercial motor vehicles begun to develop on a large scale and mechanical road traffic began to assume anything like large proportions. If we take out of the twenty years, since 1904, the six years of the war, we realise that as a matter of fact motor road transport of all kinds and our modern system of making roads has only had about fourteen years in which to develop, a remarkably short time for so stupendous a revolution. I leave it to your imagination to answer a question as to the future which can be put in terms of a rule of three. If road transport has increased from zero to a million and a quarter vehicles in twenty-five years, how many motor vehicles will

be engaged in road transport in another twenty-five. Perhaps the true answer is that probably in about ten years we shall begin to near the saturation point. To sum up the matter, we are only at the threshold of the developments possible in roads and road transport. We are, though many of us may be unconscious of the fact, still at the very beginning of a new era of transport, and though I cannot conceive that railways will ever be scrapped or lose their value in certain directions as carriers of the heaviest kinds of traffic, and of passengers at the highest rate of speed by night or day, we must revise our ideas in regard to railway and road transport and consider not only the probabilities but the possibilities which lie in front of us.

I will deal first with the question of roads, because they are naturally antecedent to the question of the traffic upon them. It is not always remembered that the cost of transport in motor road vehicles largely depends upon the state of the roads over which they run. The difference in the cost of running between a good and bad road may vary in round figures from 10d. a ton mile, in the case of a heavy lorry of the 4 or 5-ton type, and at least a 50 per cent. increase on that figure or 15d. per mile. Potholed roads, uneven surfaces, severe gradients, an undue amount of corners and constant compulsory stops on a road at once increase the consumption of motor spirit, the wear of the engine and transmission gear, and diminish the life of tyres. In addition the increased strain upon the driver is reflected in a tendency to demand higher wages, and in an increase in the number of accidents due to the uneven character of the road, for fatigue, resulting from undue vibration, produces irritability and loss of steady nerve power. A bad road is also more expensive than a good one. An inferior road may have been cheap as regards its initial cost, yet it may be much more expensive in maintenance than a well made road taken over a period of ten or twenty years.

I may remark also that I am sure that the true financial policy in regard to the principal roads of our country would be to borrow, at the at the present time, large sums—amounting to millions, if necessary—raised on and secured by road Bonds secured on the Motor Taxes,

to be redeemed year by year or at the end of a stated period. With this money we could rebuild our chief roads according to the latest and most scientific knowledge which we possess, and the saving in upkeep on them would more than pay the interest on, and redemption of such bonds. A thousand pounds per mile is not an unusual figure to take as the annual cost of upkeep in the country districts of a Class 1 road, made on the mud-bound macadam principle, or of any type except the best. Such a sum is 5 per cent. upon £20,000, and probably for about half this, say £10,000, the road could be converted and remade with concrete or bituminous macadam, or on a one or two coat principle, in such a way as to reduce the annual upkeep for at least 15 years to a negligible figure. Instead of £1,000 a mile the figure would be less than £100 per mile for a long period. This would mean an annual saving of at least £900 a year, which, for 15 years, would produce a sum of £13,500, which shows a distinct balance on the right side without reckoning any interest on the sums of £1,000 a year which otherwise would have been spent. Even after that period the road could probably be patched or the surface remade at a moderate expense, for the foundations and sub-crust would remain. In other words, we should regard in future the structure of the road as we regard the structure of a building of which the roof needs repair at long intervals, while the main structure remains still unimpaired. Therefore we must aim at building our roads as permanent and not temporary works of engineering. That is the true trend of road engineering to-day.

While on this point it is interesting to remark that the Romans, though their roads were not wide, generally about 15 ft. to 24 ft., laid them with almost monumental foundations, the ascertained thickness in many instances being between 35 in. and 48 in.; 35 in. to 46 in. being quite a common depth from the surface to the foundations. In the case of the Fosseway, between Bath and Exeter, the Roman road was made as follows :—

1. Original soil on a level with the surface of the adjacent field.
2. *Statament*—Rubble stones without lime, five inches deep at the centre.

3. *Rudus.*—A bed of concrete, broken stones mixed with lime, 15 inches.
4. *Nucleus.*—Fine pounded material, mixed with lime and well rammed, 10½ inches.
5. *Summum Dorsum.*—Paving stones, 4 or 5 inches thick, of all sizes and shapes, and firmly cemented.

There is evidence also of a form of concrete being employed, not made with the Portland cement of to-day, but with lime in conjunction with gravel, hard stone, flints and other material. And usually where the traffic was heavy the surface must have been made akin to our stone setts of to-day, a form of surfacing which I have always thought will come into favour again, especially for heavy traffic.

The gradual strengthening of the foundations of our roads and the improvement of the surfaces, follows pretty closely the evolution of the rails on our railways. Originally iron rails of short lengths were employed in many cases, resting on longitudinal sleepers, embedded in ordinary water gravel. Gradually through various stages longer lengths of rail and cross sleepers came to be used, and to-day we have the longest lengths of rail of hard steel which can be handled economically produced by the roller mill weighing in some cases 120 lbs. to the yard. These are laid on sleepers of considerable size, which rest on a road-bed of broken stone to a depth of at least 12 inches in the case of most main lines. And as regards the weights now borne by the road, the heaviest locomotive weights to-day are designed so as not to give a load of more than 21 tons on any single axle on the steel rail. This weight, moreover, only occurs in the latest type of locomotives on the L.N.E.R. Axles and their wheels have always been multiplied when weights increased. Thus we have heavy locomotives of the 4·6·2 type with six-wheeled coupled driving wheels, and ordinary bogie passenger coaches, weighing from 35 to 45 tons, borne on eight wheels, and sometimes on six, in order that the weight may be distributed and not bear too heavily on any particular point on any particular rail.

Observe in road transport the same tendency now shewing itself, and none too soon. Already we have got the six-wheeled lorry, such as the Scammell, while the eight-wheeled lorry is already being thought about and probably designed. But at the moment the road is called upon to bear axle loads which, in my opinion, are excessive, and could be avoided if the road builder and the vehicle designer would work more closely in touch with each other. The maximum weight allowed by the law to-day is 8 tons per axle, but we know in practice that this weight is often exceeded. Now, a modern railway passenger bogie coach often weighs in the neighbourhood of 32 tons, meaning a load of 8 tons on each of the four axles, and many of our transport vehicles impose an equally heavy load on the road, which is manifestly excessive. In the one case it is a question of a steel wheel running on the smooth steel rail, itself borne and buttressed up by chairs and cross sleepers and a more or less perfect road bed, while in the other case, the ordinary water-bound road, very often with insufficient foundations, has to bear a similar load, and when the surface is uneven, a bumping strain as well. At the moment it is evident, therefore, that the vehicle and the regulations governing the vehicle on the road are too far ahead in point of development, compared to the road itself, and, personally, I should favour rigid adherence to and enforcement of a weight limit of 8 tons per axle for some years to come. I should also encourage by means of differential taxation the bearing of loads in excess of say a 6 ton axle weight on more than two axles. Were this done the construction and maintenance of roads would be cheapened, the vibration as regards houses near the highway would be reduced, while there would be an economy in tyres and an increase in the safety of travelling vehicles. From a road point of view the speeds of light vehicles are unimportant and the effects on a good road insignificant compared with the weight of heavy lorries.

I should like to refer now to the system of the main or trunk roads of this island and suggest a policy. While I am always opposed to any "grabbing" policy on the part of a central Government department at Whitehall, for wisdom and economy is not found there

exclusively, and while I believe in encouraging decentralisation and assisting local endeavour, it is clear that sooner or later all our great trunk roads should be supervised and paid for by one authority out of national resources. I do not think we could adopt a better system, speaking generally, than that of France, where most important roads are classified as national roads and are managed and repaired by the Department de Ponts et Chaussées from Paris out of the general taxation of the country. Out of the 18,737 miles of Class 1 roads in England and Wales, and the 5,310 miles in Scotland, or 24,047 miles in all, probably at least half or about 12,000 miles should be made national roads. These 12,000 miles would be kept up entirely out of national and not out of local funds, but local administration would be advisable on the score of economy. Such a system would be also to the advantage of the heavily pressed ratepayers in the agricultural districts in both Scotland and England. And for the remaining 12,000 miles I would suggest that 75 and not 50 per cent. of the upkeep cost should be paid to the local authorities towards repair and maintenance. Class 1 roads are becoming less and less local in character, and well over 75 per cent. of the traffic upon them is through and long distance traffic.

Towards Class II. roads, many of which are more heavily trafficked than were Class I. roads five years ago, 50 per cent. of the annual repairs bill should be given by the Ministry of Transport. Rural roads, the maintenance of which is one of the biggest problems with which we have to deal to-day, should be classified into rural roads of first and second class character. Regular help should certainly be given to the former classification, instead of an inadequate and irregular dole which is now given at rare intervals when Parliamentary pressure is brought to bear. If the Road Fund, amounting to about £14,000,000 a year, at the moment is insufficient for these reforms, Parliament should be asked to vote every year an additional sum as part of the National charges rightly borne by the Nation as a whole, and as a contribution from the Army, the Post Office, and other Government departments using our roads.

Before I pass on to the second section of my lecture, that dealing with vehicles and traffic, I would like to point out that roads are becoming increasingly the arteries and veins of our national life. Upon them depends to a large extent the solution in whole or part of housing, the cheapening of agricultural production, the social amelioration of our villages, and the accessibility of our towns.

We in the South have heard rumours that in Glasgow there have been of late slight differences of opinion on housing questions, and that one of your local members has evolved a wonderful solution of the problem. But most of you know how much locomotion concerns housing, and the more the subject is studied, the more it appears that better conditions can often be obtained by increasing accessibility to new suburbs or to sites not yet fully built upon, rather than by multiplying the number of humans on already too densely occupied ground. Later on I will again refer to this aspect.

We now come to the consideration of the vehicles which use the roads of this country. I assume you know how small in proportion nowadays is the horse-drawn traffic to mechanically propelled traffic, and I shall not weary you with many statistics in order to prove what is nowadays an undisputed fact. But it is not always realised how high the proportion is of mechanical traffic confined to other traffic amounting to 90 to 95 per cent. on the Class I. roads, and fully 80 per cent. on Class II. roads. In fact the number of horsed vehicles is diminishing with every year, and except for a small amount of local traffic the horse before long will have disappeared as an animal used for traction on our roads. On the other hand, the actual increase in motor vehicles has been little short of astounding. According to the last report for the period of November 30th, 1922, to December 1st, 1923, of the Ministry of Transport, there were 1,141,400 motor vehicles licensed. To this figure may be added an average annual increase of at least 15 per cent., making the total number of vehicles in use to-day approximately 1,312,610. Of this total in round numbers, 400,000 are private cars, 450,000 motor cycles, these two classes representing over 60 per cent. of the total. Commercial goods vehicles on the other hand amount to about 200,000, or about one-

sixth of the total. It is clear, therefore, that the privately-owned vehicle (including motor-cycles) outnumbers the commercial vehicle by about four to one. Now, it is for the commercial vehicle, especially for the heavier types that our modern roads have to be strengthened so greatly nowadays. Whether it is fair to make the privately-owned vehicle pay so much more heavily in proportion to wear caused is a matter of opinion, but it is quite clear that it is mainly the revenue from the private vehicles, amounting to about £8,000,000 this year, which is the main source from which comes the money for repair and improvement. In the last year on record, commercial vehicles and motor hackneys added together only produced about £5,600,000. It may or may not be a wise policy to thus subsidise commercial motor vehicles at the expense of the users of the lighter traffic, and also at the cost of the ratepayers. And I have always realised that there is something in the contention put forward by the railway companies that they as ratepayers are compelled to pay for the upkeep of the permanent way on which their rivals run a competing business. There is an answer to this contention, namely, that the road is free and open to all, whereas they own and operate a private road with rails upon it. There are also other matters which enter into this particular controversy, on which I have not time to dilate to-night. But it is undeniable that from a logical point of view, commercial goods vehicles do not pay their due share of the road upkeep compared with the expense they cause in construction and maintenance. Private cars taxed on horse-power produce an average of £16 18s. 6d. per vehicle, while commercial goods vehicles average a payment of £21 7s. 0d., and motor hackneys £25 11s. 6d., but the lower average for private cars include those tens of thousands of small vehicles which are used increasingly by all classes and whose use of the roads is less damaging of all to the surface. The increase in the number of motor vehicles since 1914 is shown from the following figures :—

In 1921	there were registered	873,665	motor vehicles.
In 1922	,, ,,	933,308	,,
In 1923	,, ,,	1,141,400	,,

In the United States, according to the report of the National Automobile Chamber of Commerce, there are 15,000,000 motor vehicles, or about 1 for every eight persons, while the revenue derived from vehicle and motor spirit taxation amounted in 1923 to 450 million dollars, or over 90 million pounds sterling. The Highway Bonds issued amounted to 1,222 million dollars, or about 650 million pounds. These figures are striking and suggestive. If we calculate on the basis of one vehicle for every ten of the population here, we shall have before long 4,500,000 vehicles, or four times as many as to-day. And we are suffering already from congestion on some of our highways.

The following figures taken from the report of the National Automobile Chamber of Commerce in the United States are interesting as bearing upon the question of the resistance of various types of road surfaces and the cost of haulage :—

Rolling Resistance—Motor Lorry, Solid Tyres, 10 m.p.h.

	Tractive Resistance.
Earth Roads, well maintained, ...	55 lbs. per ton.
Gravel Roads, well maintained, ...	45 lbs. per ton.
Paved Roads, well maintained, ...	35 lbs. per ton.

Note how the motor vehicle and the improved highway have lowered the tractive power required to move tonnage.

Vehicle operating costs on various types of improved roads (Cost in Halfpennies per ton mile).

TYPE OF SURFACE.	Solid Tyre Lorry Speed 10 m.p.h.	Pneumatic Tyre Lorry Speed 15 m.p.h.	Ordinary Motor-Car Speed 23 to 25 m.p.h.
Average Portland Cement, concrete, asphalt or bitumen, ...	8.00	8.3	10.00
Best Portland Cement and asphalt filled brick, ...	7.75	7.70	9.3
Best gravel, yearly average, ...	8.5	8.8	10.9
Ordinary gravel, yearly average, ...	9.0	9.40	11.8
Waterbound macadam, well maintained, ...	8.7	8.25	11.1
Bituminous macadam, well maintained, ...	8.5	8.80	10.6
Average sheet asphalt, at yearly average temperature, ...	8.10	8.3	10.00
Average asphaltic concrete at yearly average temperature, ...	8.00	8.3	10.00
Best earth, well packed by traffic, yearly average, ...	9.0	9.40	11.79
Ordinary earth with light traffic, yearly average, ...	9.3	9.95	12.6

A five-ton lorry operating an average of 50 miles daily, making 250 ton-miles per day, for 300 days, means 75,000 ton-miles per year. On the basis of the cost figures I have given, you will note that the difference of ¾d. per ton mile between operating on an ordinary country road and a good paved road would amount to about £230 per year. Between a rural road and a well made gravel road the saving on the operation of the lorry would be about £76 per year.

You probably know that it requires a pull of 15 lbs. to move a ton borne on a clean steel wheel on a clean steel rail, whereas it requires a pull of about 45 lbs. to pull a ton in a solid rubber-tyred vehicle on an average macadam road. But the best macadam is now far surpassed in smoothness by a road with a bituminous coating of slag asphalt or similar surfaces. The pull required is now about 30 lbs. instead of 45 lbs., so to that extent the natural advantages of railed over road transport is reduced. Moreover, labour and handling has become more expensive while power has become cheaper. The result is that the greater expenditure in wages in connection with railed transport per parcel or per passenger or ton carried has completely wiped out the initial advantage of the expenditure of less power. That is the chief scientific reason for the gradual flow of traffic from the rail to the road.

Apart from any use of motor vehicles for purely pleasure purposes, which is now a very small percentage of the total traffic, tens of thousands are used every day by professional and business men for purposes of collection and distribution of all kinds of merchandise. One of the most notable increases of late has been seen in the number of motor omnibuses and char-a-banc running on regular routes either every day or so many times a week in rural districts. In England, and I believe on this side of the Border too, there are few villages which are not connected now with larger towns or railway stations by this means, and the opening up of country districts in this way has been of great service to the rural population, besides to some extent minimising the tendency for population to leave the country for the towns. While controversy still wages between the

advocates of tramways and of motor omnibuses working in densely populated urban areas, there can be no question that beyond purely urban limits, the tramway is not a practical proposition from an economic stand point. As regards railways, their managers are also beginning to realise that short hauls had better be left to road vehicles. Door to door passenger transport by road means a saving to the traveller in time, in shoe leather, and in fatigue at the beginning and end of the day.

I have touched already on the question of transport and housing, and pointed out how intimately they are connected, but it is only now becoming realised that it is no good developing the suburb of a town before the means of communication, both in roads and transport between the suburb and the town are brought up to a high standard of cheapness and efficiency. We should try nowadays to think of problems of urban and suburban locomotion in terms of time rather than of miles, and I venture to coin the word " timeage " on this occasion, as contrasted with the word " mileage." Now it is obvious that if a workman of any kind, be he professional, manual, or clerical, lives a certain distance from where his work lies, what matters to him is not the number of miles which separate these two places, but the time he takes getting from the one to the other. And if a man cannot afford to live say more than 20 to 30 minutes away from his work, it is better that he should be conveyed in the same time quickly to a point further from the centre of the town, rather than be conveyed slowly to a place which in mileage is nearer. All students of social reform are agreed that we must endeavour to decentralise our bigger towns, or at any rate prevent further centralisation taking place. But this can only be done by quicker and cheaper locomotion, which means a better train, tram or motor 'bus service to the districts further out and for improved road transport better and wider roads are needed. And it is here that the mechanical road vehicle can help in a special degree. Where a town spreads it is desirable that the more distant suburbs should increase, for, as a rule, land is cheaper, the nights for the sleeper more free from noise, and the atmosphere for husband, wife and children better. For such

development the motor vehicle is the most suitable, for it can extend its routes as the suburb increases and spreads. The tramway, with its necessary equipment of rails and permanent way, cables, and central generating station, is only in my opinion suitable where the traffic is very heavy and the population dense. Moreover, the motor vehicle can on holidays and other days be used for excursions into the surrounding country, and the town dweller can at last see something of the beauties of his native country without having to hustle to the railway station, sit for some time in a crowded compartment, where tobacco, sweets, and children combined, produce an aroma not always pleasant. There are plenty of beauty spots around your great towns in Scotland, near Glasgow, Edinburgh, Perth, etc., not well enough known to the majority of your town dwellers. Let me draw the attention of this gathering of my fellow Scots to the great benefits which the public and private motor vehicle brings to remote villages. The desire for a quickened life is one of the most potent and obvious causes of the influx into the towns. This desire is the natural result of a higher standard of education, of a desire to see and know, to hear and acquire, and to get out of the rut of a dull daily life. The motor vehicle, in the first place, and wireless telephony in the second, has already achieved much for the country dweller, for without having to abandon his country home he or she get to their doors the means for the quickening of intellect and the feeling grows that the country dweller is no longer out of touch with the great outer world.

I would also point out that with only four great railway systems, each of them possessing a complete or partial monopoly in their districts, it is important that the public at large should have some alternative means of travelling, and the use of mechanical road vehicles remains the most efficient check to the misuse of railway monopoly.

Finally, I say about vehicles what I said about roads—that we are only at the beginning of this new era of locomotion by road. We have already six-wheeled vehicles for passengers as well as goods. Later on we may see the use of more, possibly of 8 or 10 wheels. We may see also sleeping cars on the road as there are sleeping cars on

the railways. Twenty years hence, with less expensive motor tyres, and possibly some form of gas suction instead of petrol at about one-tenth of the price per unit of power developed, all locomotion by road will become much cheaper, possibly half or one-third the cost of operating per mile or per ton to-day. We may have our main roads so improved that the maximum gradient will not exceed 1 in 30, as on the new roads near London, and instead of vehicles producing their own light, all main routes may be lighted by night. Some day, not far hence, the passage of a motor vehicle over the best roads will be comparable in comfort to the best spring railway coach of to-day, travelling over the best type of permanent way. And the speeds compared with to-day will be higher.

Now, I have detained you too long, and I must come to my conclusion. It is not easy to make a lecture on transport and roads an attractive one from a popular point of view, but if I have set your minds thinking and stirred somewhat your imaginations, I shall have achieved the task which I set myself. For the Glasgow Philosophical Society contains the type of member who makes sound public opinion.

Rudyard Kipling has said that " Transportation is Civilisation." It is more to-day to this country. It is the greatest force we possess to quicken and improve our daily life, to ameliorate social conditions, and to cheapen production and distribution. What more can you ask of any modern development. Those of us who have been disciples and missionaries in the movement as long as myself, and have tried to look ahead, are not thinking of singing *Nunc Dimittis* yet. But we, and you, have seen enough happen already to make us thankful that this great and wonderful development of road transport has come in our own time for the good of the country.

Ancient and Modern Medicine.

By Professor RALPH STOCKMAN, M.D.

(*Read before the Society, 3rd December,* 1924).

Different authors have treated very differently of the origin of ancient medicine. The great English physician, Sydenham, dealt very briefly with the whole question, his intensely practical mind probably deeming it of little importance for everyday practice. He says, "As there is no man can tell who first contrived the use of houses and clothes to defend us from the injuries of the weather, so the beginning of the art of physic can no more be discovered, for this art has been always in use, though it has been cultivated either more or less according to the various dispositions of times and countries," and so he summarily dismisses the whole subject as prehistoric and incapable of elucidation.

Probably the idea of employing natural products as remedies in illness arose from observing the reactions of the body to these substances when used as foods, and the very obvious effects of some of them as emetics, purgatives, and so forth. Be this as it may, it is certain that no tribe has ever been discovered which did not possess some crude skill in the use of medicines, and at the present time certain of the lowest of them are experts in the manufacture of arrow and fish poisons to obtain food. At a stage slightly higher we find the specialised medicine-man, an important functionary occupying an influential position in the tribe, and frequently showing great skill in the use of poisons, as in trials by ordeal, which are conducted with much ceremony under his control and direction, while a considerable knowledge of rude medicine and surgery always forms part of the general tribal culture. As regards the origin of surgical knowledge, there is of course no difficulty. It arose naturally from the necessity of treating wounds received in war and in hunting.

When we come to written documents, probably the Hindu sacred books or vedas furnish the earliest theories of pathology extant—namely, that of demoniac possession. Storms, earthquakes, floods, and other terrifying phenomena were confidently ascribed to evil spirits, and the incidence of epilepsy, insanity, delirium and illness generally, was reasonably enough explained on the hypothesis that the victim was possessed of a devil which could be cast out if appropriate measures were employed. The natural result of these beliefs was to apply for help to the priest as the person of all others in closest touch with deities and demons. The exorcist or caster out of devils was an important person as late as in the early Christian church, and traces of him still remain among ourselves in the forms of charms, mascots, babies' rattles, faith-healing, and other curious survivals. This was the origin of the priest-physician, a combination which continued down to comparatively late Greek times in civilised communities, and still flourishes among the less enlightened portion of mankind.

It was in Egypt that medical knowledge first became systematised and began to assume the form which it now has. The invention of the alphabet and writing had rendered it possible to stabilise and make permanent human knowledge and experience, and as early as 4,000 years before Christ, the priests had adopted the habit of keeping records of their cases and cures. From this there was gradually evolved a system of medical and surgical practice with elaborate regulations. It was a land of specialists, one physician was confined to the study and treatment of one disease, it was a state service paid for by the treasury, and doctors were required to follow the rules laid down by the state officials. If they failed to do so and harm resulted, the patient could recover damages at law, if they faithfully followed the regulations they were held blameless, no matter what happened. They practised surgery and used medicinal preparations much like those of to-day, but owing to the rigid government rules and official interference, all initiative and originality were curbed, and knowledge tended to remain more or less stagnant. The practice of medicine became a matter of memory and routine, rather than of

brains. Their common diseases were such as we ourselves suffer from, but much fewer in number—eye troubles, gout, rheumatism, anaemia, asthma, tumours, and among their remedies were such well known drugs of to-day as opium, castor oil, iron, squills, and aloes. It was from Egypt that the early Greek civilisation derived its knowledge of medicine, but by the natural genius of their race the Greeks ultimately so improved upon and transformed it that they laid the foundations of an enlightened pursuit and study of the art of healing, the methods and principles of which have endured to our own time and have not been much altered in 3,000 years. But this was not done in a day. In the Iliad (*Circa* 1200 B.C.) Æsculapius is a Thessalian chief skilled in medicine and surgery, but by the 8th century B.C., we find him the Greek God of healing, the reputed son of Apollo, with many temples dedicated to him throughout Greece. These temples were under the charge of priests, the sick resorted to them for help and cure, and ultimately they became to all intents and purposes hospitals in the modern sense of the word with students, teachers, and a great accumulation of professional experience and tradition. In time the priest became the priest-physician and insensibly the priestly part of his office faded into the background, leaving the physician pure and simple. The most celebrated of these temples was at Cos, an island in the Aegean Sea, where Hippocrates, the father of medicine and the most famous of all physicians, flourished in the 5th century B.C. The so-called "works of Hippocrates" are the records and writings of numerous members of the teaching staff, their lectures, textbooks, and notes of cases, and they form the basis of all our medical knowledge of to-day. Scottish medical students on graduation still swear to abide by the terms of the Hippocratic Oath in their professional dealings and conduct, and Hippocratic nomenclature is still largely in use. The great merit of Hippocratic medicine consisted in the substitution of observation, reasoning, and experience for theory and supernaturalism, its weak points are the absence of active treatment and exact diagnosis. Ancient Jewish medicine is merely an echo of the Assyrian and Egyptian traditions.

Roman Medicine was Greek medicine. A great city like Rome had, of course, many eminent practitioners, and a number of them wrote quite informative and respectable medical treatises, but with the exception of Galen, who was a Greek and wrote in his native tongue, none of them has exerted any appreciable general influence. Then came, early in the sixth century, the subversion of the Western Roman Empire by the barbarians of Germany and Scythia, and Western Europe was plunged into intellectual darkness for centuries. Any learning that survived was confined to a few great cities and to churchmen, but perhaps we can best realise the actual state of affairs when we reflect that during the dark ages and mediaeval times many even of the great nobles could barely sign their own names. In Scotand, as late as 1496, James IV. had to compel by act of parliament all barons and freeholders to give their sons some slight elementary education. Ordinary people did not possess manuscripts, the art of printing had only been invented about fifty years previously, and consequently there was not much to be gained by learning to read and write. Medicine as a learned profession completely disappeared from Western Europe and its first revival was the School of Salerno (near Naples) in the ninth century, but only in a very small way. The story of its wider re-introduction is one of extreme interest. Although Rome had fallen, Constantinople remained as a centre of culture and learning, from which Greek medical knowledge spread to Damascus, Bagdad, and Alexandria, where Universities had been established by a series of enlightened Caliphs. Here Hippocrates and Galen were eagerly studied and their methods and practice adopted by the great Arabian physicians. With the Moorish conquest of Spain and the fall of Constantinople, the works of Galen and the Arabian Avicenna especially became widely known in Europe, and obtained complete and universal authority till the 16th century. Nothing else was known or taught to generation after generation of medical students for some five centuries. Thus for about a thousand years there had been no great advance or change in the study of medicine or the treatment of disease. It is a human tragedy. But the 16th century saw a new start made in Europe, notably in Italy, France, England, and the

Low Countries, and medical research and learning then became and has since remained part of the general activities of all civilised nations. Vesalius (1514-64), a Belgian, who worked in Italy, revived the practical study of anatomy; Ambroise Paré (1517-90), a Frenchman, wrote his great treatise on surgery; Harvey, an Englishman, demonstrated the circulation of the blood (1628), and Morgagni an Italian, laid the foundations of pathology. Sydenham's (b. 1624) writings as a physician are studied to this day, and Leeuwenhoek, a Dutchman, used the microscope to good purpose in elucidating the minute structure of the body tissues. These men were succeeded by numerous and indefatigable workers on similar lines, by whose enthusiasm and ability the bounds of our knowledge were greatly extended. Cullen, the great Scottish physician, who died in 1790, confesses that to him "the nervous system and its diseases is an inexplicable mystery," but forty years later Sir Charles Bell had demonstrated the existence of sensory and motor nerves, and later still Marshall Hall established the reflex functions of the spinal cord, two discoveries which opened the way for our present very complete conception of nervous diseases.

Laennec, a French physician, invented the stethoscope in 1816, an instrument much associated in the lay mind with doctors, and one by means of which the diagnosis of lung and heart diseases has been rendered much more accurate. The history of its discovery is interesting. One day in passing through the gardens of the Louvre, Laennec observed some boys at play scratching the end of a long wooden pole and listening for the sound of the scratch at the other end. Next day he listened to a patient's heart with a tightly-wrapped roll of paper—and the stethoscope was invented. Time will not permit me even to allude to many such discoveries in all departments of medicine.

When the nineteenth century was well on its way the general increase of scientific knowledge began to exert a marked effect on medicine. Research workers increased in numbers and better instruments and methods were available for them. The perfection of the microscope has proved of enormous importance. Among its

innumerable services is to be counted Schwann's enunciation of the cell-theory: "There is one universal principle of development for the elementary parts of the organism, however, different, and that principle is the formation of cells," a dictum which has become the basis of all study in biology.

Chemistry also has brought us many new remedies and certain great improvements in the application of old ones. Pure chemicals were substituted for such bulky things as burnt sponge and powdered woods, and alkaloids and other active principles of plants were employed in place of the crude drugs. The reasons for the actions of medicines were more closely scrutinised, a more critical attitude as to their real value was developed, and new remedies were sought for and tested on definite lines with many successful results. The practical possibility of producing anaesthesia by means of laughing gas and ether was worked out in America, and by 1847 this inestimable boon to mankind was in universal use. Local anaesthesia by means of cocaine was realised in 1882. Physics has furnished us with the help of the x-rays, and chemistry with the details of many metabolic disturbances in disease.

Most of these things, important as they are, are, however, only advances in our methods and in efficiency, they signify no fundamental change in principles. But the nineteenth century witnessed also the greatest single change, and probably the most far-reaching one, which has ever taken place in medical theory, in the discovery and realisation of the dominant part which bacteria and other minute organisms play in the causation and natural history of disease. We owe this entirely to Pasteur, a French professor of chemistry and physics, who was not a doctor and had no previous medical training. In passing I may say that such anomalies are not rare in the history of human progress. It was Jean Astruc, physician to Louis XIV., who founded the whole science of biblical criticism by his analysis of the book of Genesis, and it was a clergyman, the Rev. Edmund Cartwright, who, without any previous training or knowledge of mechanics, designed the first power-loom and made automatic weaving an accomplished fact. Pasteur's genius has revolutionised our whole

outlook and therapeutical aspirations in infectious diseases, and has enabled us to treat two of them, hydrophobia and diphtheria, with distinguished success. One hundred years earlier, Jenner had discovered the value of vaccination with cow-pox virus in warding off small-pox, but it had remained an isolated and unexplained phenomenon until Pasteur threw light on the whole subject, and by artificially attenuating the virulence of the specific microbes, produced similar vaccines for several animal and human diseases. Lister applied his discoveries to surgery with results which are so well known as only to need mention.

Another direction in which medicine has made great advances in our own time is in the increase of knowledge regarding the important part which certain glands play in the bodily economy. Nutrition, growth, and the smooth working of the whole complicated organism are dominated and regulated by the chemical secretions which these glands supply, and when functional or organic defects take place in them many well-known diseases result. Disturbances in the thyroid gland are the cause of myxoedema and exophthalmic goitre, diabetes is due to deficient working of the pancreas, and in both these instances efficient treatment is possible by utilising the corresponding glands of animals. At the moment active endeavours are being made to extend our knowledge in this special field.

The recognition of the part which animals in contact with man play in the transmission of disease is another striking result of recent research, and has had an enormous influence on the development and efficiency of preventive medicine. Malaria and yellow fever are carried from man to man by mosquitoes, typhus and trench fevers by the louse, and plague by the rat; while certain cattle diseases are transmitted through ticks. It was yellow fever and malaria which brought failure on the first Panama Canal scheme, but when the Americans took its construction again in hand, these plagues had lost their terrors and were easily kept in check, owing to the knowledge gained from research into their natural history and modes of infection.

From a hasty and superficial survey, such as I have just given, the impression might be gained that for some centuries past all has

been, and now is, well with medical science and practice, and that it has gone on uninterruptedly in an even course from betterment to betterment. This unfortunately does not represent the true state of the case. When human progress is judged by a sufficiently large scale of measurement it is abundantly evident that there is advance, but man has never progressed in a straight line and with an unbroken front as it were, his path has too often gone off at a tangent and has even sometimes been partially or entirely retrograde. This is as true of mankind medically as it is politically. Each succeeding generation of doctors is very conscious of the failings and demerits of its more immediate predecessors, and there can be no reasonable doubt that at any given period of time a proportion of our medical theory and practice has been steeped in ignorance and error. Some periods have been worse than others, but this may be said, that at all historical times there has always been a considerable volume of accurate therapeutical help available for suffering humanity. Uninformed and premature theorising from insufficient or faulty premises has in all times been the bane of medicine, and principles or beliefs so formulated have been allowed too often and too deeply to dominate practice. Numerous instances of this, both great and small, can be readily cited, but I shall confine myself to a very few examples. The theory of humors as the cause of disease, which dates from Hippocrates and is itself fallacious, led for a long period to excessive bleeding, purging, and sweating, the idea being to evacuate these harmful and poisonous substances from the system—a reasonable enough practice if only the premises on which it was based had been sound. But many of these beliefs, even in recent times, have been fantastic, such as the "doctrine of signatures," which postulated that every natural substance which possesses a healing action has this indicated by some obvious external characteristics, as yellow turmeric to cure jaundice, or the blood-stone to stop bleeding. Preconceived ideas, the powerful influences of early professional education, an over-enthusiastic value attributed to certain medicines or modes of treatment, fashion, ultra-conservatism equally with the desire for novelty, have all had and still have their share in hindering and deviating progress.

Curiously enough sound theory is not a necessity for sound and successful treatment, as witness the highly skilled application of cinchona bark in malaria centuries before the malarial parasite or quinine were dreamt of, and while very erroneous views were held as to the cause and spread of the disease. On the other hand with perfectly sound theory our methods and means of cure are too often sadly lacking in efficiency, as in the treatment of pneumonia and tubercle.

In conclusion a few words as to the present and future outlook of medicine may be of interest. To every thoughtful mind preventive medicine, using the term in its widest sense, must take first place. This is primarily a matter of medical knowledge, and secondarily of organisation and money. Certain things can only be done on a national scale and by the central government, others by municipalities and education authorities, others by the family doctor, the individual, and the family. Much has been done by good water supply and drainage. Plague, cholera, small-pox, typhus fever, leprosy, scurvy and some other diseases have no terrors now for modern civilised countries. Malaria and yellow fever can be dealt with if there is sufficient inducement. Tubercle is being slowly but surely banished, and a beginning has been made with venereal diseases. Industrial diseases also have been largely taken in hand. There still remains, however, a very formidable list with regard to which little has been accomplished—cancer, pneumonia, influenza, scarlet fever, measles, septic fevers, and many others.

Infant welfare schemes, medical inspection of school children, and maternity centres are at work now to nip disease and deformities in the bud, and are bound in time to have a great influence on the public health. The importance of individual and family attention to general good health, to personal cleanliness, exercise, fresh air and healthy amusements, is hardly realised by the bulk of our population, but I am bound to say the attainment of these things is hard for the masses in our industrial towns which still remain a blot on humanity and civilisation, with their smoky atmosphere, drab streets, wretched housing, and general dirt. These conditions induce in all of us a

lowering of vitality, both physical and psychical, which is very inimical to good bodily and mental health and to our happiness and efficiency generally.

Next in importance to preventive medicine comes the attainment of a more accurate and specific treatment of disease. With our present knowledge we are reduced to treating the great majority of germ diseases on general principles—nursing, dieting, alleviation of pain, and sleeplessness and other disturbing symptoms—which are calculated to sustain the patient's strength and to enable him to overcome the infection. In a certain number of such diseases, notably diphtheria, dysentry, tetanus, malaria, syphilis, and rheumatic fever, definite and accurate remedies are in our hands, and the search for others is at present one of the great goals of medical activity, but I need hardly say that it is one beset by many difficulties and very hard to attain even for a single disease.

Even our failures, however, in this direction have sometimes led to success. It was in the search for a remedy to combat sleeping sickness that salvarsan was discovered, and attempts to make morphine and quinine synthetically have resulted in a number of new and valuable drugs to relieve pain and fever.

The Evolution of Electrical Knowledge.

Presidential Address by CHARLES R. GIBSON, F.R.S.E.

(*Read before the Society, 14th January,* 1925).

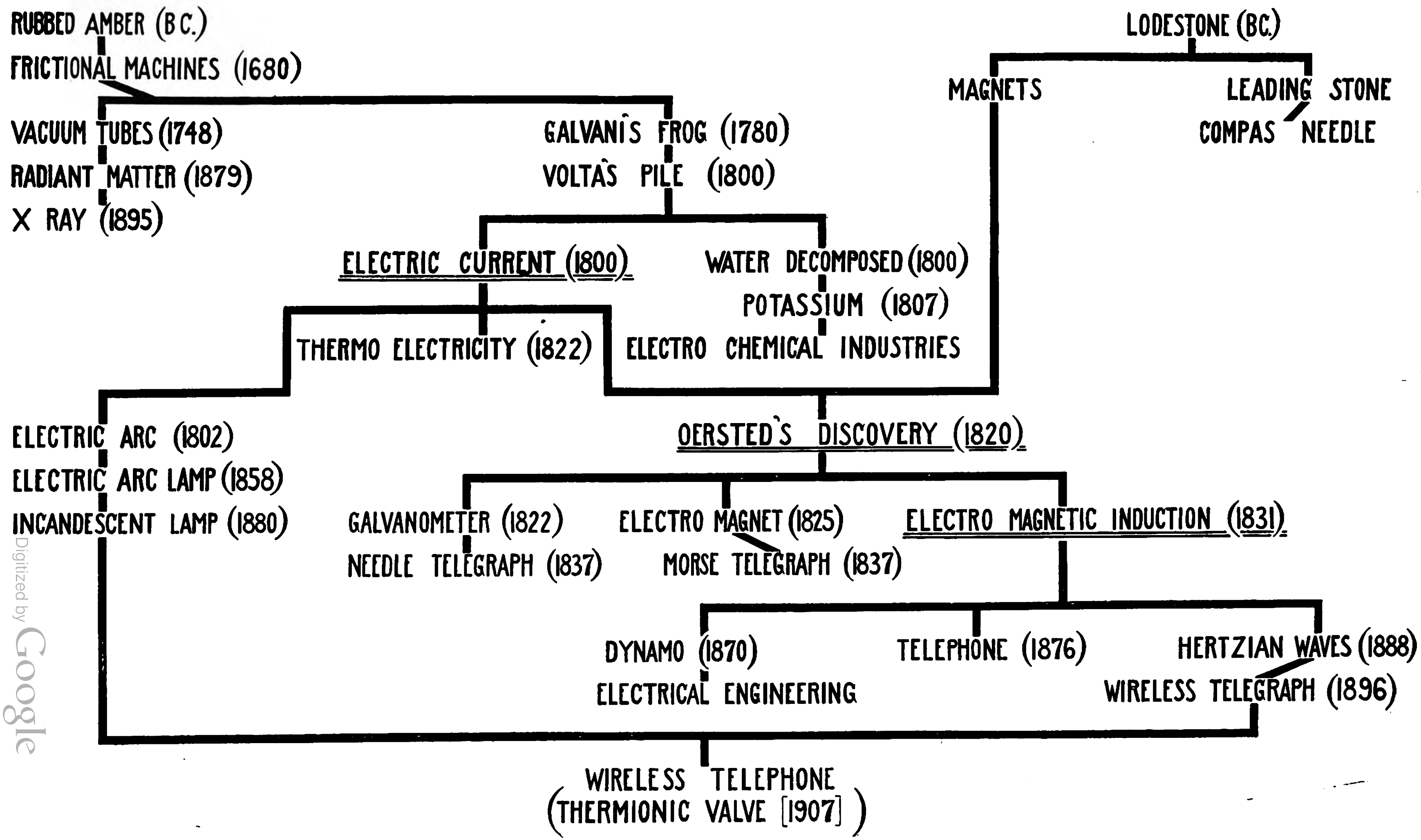
The purpose of this address is to give a bird's eye view of how our knowledge of Electricity has come about from the days when it was discovered that a piece of rubbed amber attracted light objects to itself.

It will simplify matters if we divide the subject of Electricial Knowledge into two parts, practical and theoretical, and treat these divisions separately.

So that the spoken address may not be burdened with too much detail, I propose omitting the names of discoverers and inventors except in cases where the names are well-known or the discoveries and inventions of primary importance. I have placed a genealogical tree upon the blackboard, dealing with the practical side. I shall not refer to this, but it may serve as a guide to you as we go along.

Taking the practical side first, we commence with the rubbed amber phenomenon, not that it was put to any practical purpose, but because it was the first electrical experiment ever made, and also because in course of time it led to the invention of simple electric machines. The rubbed amber phenomenon is recorded by one of the seven wise men of Greece as early as 600 B.C. It was known also to the ancients that jet acted in the same manner as amber.

It is strange that it was possible for these two substances to reign supreme for more than 2,000 years as the sole possessors of this attractive power, while so many common objects were ready to show the same phenomenon. The explanation is that the people of those days preferred philosophy to experiment, deeming experiments beneath their dignity.


RUBBED AMBER (B.C.)
FRICTIONAL MACHINES (1680)
VACUUM TUBES (1748)
RADIANT MATTER (1879)
X RAY (1895)
GALVANI'S FROG (1780)
VOLTA'S PILE (1800)
ELECTRIC CURRENT (1800)
WATER DECOMPOSED (1800)
POTASSIUM (1807)
ELECTRO CHEMICAL INDUSTRIES
THERMO ELECTRICITY (1822)
LODESTONE (B.C.)
MAGNETS
LEADING STONE
COMPAS NEEDLE
ELECTRIC ARC (1802)
ELECTRIC ARC LAMP (1858)
INCANDESCENT LAMP (1880)
OERSTED'S DISCOVERY (1820)
GALVANOMETER (1822)
NEEDLE TELEGRAPH (1837)
ELECTRO MAGNET (1825)
MORSE TELEGRAPH (1837)
ELECTRO MAGNETIC INDUCTION (1831)
DYNAMO (1870)
ELECTRICAL ENGINEERING
TELEPHONE (1876)
HERTZIAN WAVES (1888)
WIRELESS TELEGRAPH (1896)
WIRELESS TELEPHONE
(THERMIONIC VALVE [1907])

Not till about the year 1600 did anyone try if other substances would behave in the same manner. Then one of Queen Elizabeth's physicians, Dr. Wm. Gilbert, found that glass, sulphur, resin, and many other substances acted in the same way as amber.

It was Gilbert who suggested the word *electric* from *electron*, the Greek word for amber, so we have a memorial to the amber discovery in the word *Electricity*, and kindred words.

In 1680, people made simple machines to do the rubbing on a larger scale than could be done by holding the substance in one hand and the rubber in the other. The first machine was simply a ball of sulphur mounted on a spindle to which was attached a handle so that the ball could be revolved while the hand was pressed against it to produce the friction. Then followed glass cylinders and glass plates with cushions as the rubbers, and from these were evolved the modern influence machines in which there is no actual friction.

In 1748 it was discovered that the electric discharge from these machines would produce a beautiful glow when passed through a tube from which the air had been pumped. It had been observed at a much earlier day that when a globe of rarefied air was electrified there was a luminosity within the globe.

Here we have a series of vacuum tubes containing air at different degrees of rarefaction. It will be understood that in no case can the tube be completely exhausted of air. The glow in the tube is due to the flying particles of electricity bombarding the rarefied air; a discharge of electricity through a rarefied gas.

These vacuum tubes remained as interesting experiments until 1879, when Sir William Crookes suggested that they contained what he called *radiant matter*, which we shall consider later and which we know now to be a discharge of particles of negative electricity shot across the vacuum within the tube. It was when working with one of these vacuum tubes that Roentgen discovered X rays in 1895. These X rays are produced by the bombardment of the particles of electricity, which strike a target, within the tube, and set up waves in the surrounding aether of space.

Electric machines led indirectly to the discovery of the electric current in 1800.

An electric discharge may be pictured as a wild rush of an accumulation of particles of electricity along the conductor, while we picture the electric current as a steady progression of these particles.

The first step towards the discovery of the electric current was made in 1780, in the laboratory of Galvani, a Professor of Anatomy in Italy.

Galvani's own account of the discovery is given in these words :—

"I had dissected and prepared a frog, and laid it on a table, on which, at some distance from the frog, was an electric machine. It happened by chance that one of my assistants touched the inner crural nerve of the frog with the point of a scalpel, whereupon at once the muscles of the limbs were violently convulsed.

"Another, who used to help me in electrical experiments, thought he had noticed that at this instant a spark was drawn from the conductor of the machine, but when he drew my attention to this, I greatly desired to try it for myself, and discover its hidden principle. So I, too, touched one or other of the crural nerves at the same time that one of those present drew a spark, and the same phenomenon was repeated as before."

Galvani then wanted to try the effect of lightning and also of atmospheric electricity in calm weather. He fastened a brass hook in the spinal marrow of a frog's legs and hung this on an iron lattice which was in his garden. He found the legs twitched even in the absence of a thunderstorm. He suspected this was due to changes of electric condition in the atmosphere. He thought that electricity from the atmosphere had slowly entered the animal and accumulated in it and that it suddenly discharged when the brass hook came in contact with the iron lattice.

Another Italian, Volta, who was a Professor of Natural Philosophy, could not accept this idea of the electricity being inherent in the animal, and he suggested that the electricity resided in the two dissimilar metals, and that there was a discharge between them when they were placed in contact. It is evident that he tried at first to

combine his ideas along with Galvani's. Volta's own words are :—

"The metals used in the experiments, being applied to the moist bodies of animals, can by themselves, excite and dislodge the electric fluid from its state of rest, so that the organs of the animal act only passively."

The dispute regarding the frog was not settled in Galvani's time, for it was a year after his death when Volta made the important discovery which led on to the invention of the electric cell or battery.

In the Spring of 1800 Volta made a pile of metal discs of dissimilar metals, zinc and copper. Instead of using the moist flesh of the frog, he used pieces of cloth moistened in acidulated water. Here is a model of how he built up his pile, a disc of zinc and a disc of copper, then a piece of the moist cloth, another couple of discs, and another cloth, and so on.

Volta found that when he connected the top disc of copper to the bottom disc of zinc there was a flow of electricity from the copper to the zinc. The frog was left out in the cold ; its function had been merely that of an indicator.

It was an easy step from the pile with its moist cloths to the placing of the two metals in a vessel filled with acidulated water. Probably it was suggested by the cloths in the pile drying up quickly. In any case this was the invention of the electric battery and the principle upon which all primary batteries have been made.

An important discovery was made by two Englishmen when working with the very first voltaic pile made in this country. When experimenting with this it was observed that when the electric current was passed through water, bubbles of gas escaped from the end of one of the wires, while the end of the other wire became oxidised. When the wires were replaced by platinum, which would not oxidise, bubbles of gas escaped from both electrodes. When these gases were collected it was found that they were oxygen and hydrogen, of which water was known to be a compound ; we say the water is being decomposed, though that is not scientifically correct. It is necessary to add a little salt or acid to the water. Pure water is of itself an insulator and would not conduct the current.

Here we have a vessel filled with acidulated water, and when we pass an electric current through it we get H. and O. gases. Instead of collecting these separately at the two electrodes, we allow the gases to mix and pass through this tube. We allow the mixture of gases to escape into another vessel filled with soapy water, so that bubbles are formed on the surface. These bubbles are filled with a mixture of Oxygen and Hydrogen gases, and this mixture is explosive, so we can easily test the presence of the gases by applying a flame to them, whereupon you hear a loud report and the gases again link together to form water.

Here we have another experiment which shows the separation of lead from a liquid. The current is passing through a solution of lead acetate which is being decomposed and the metal is being deposited on one of the electrodes. This also forms the basis of electro-plating.

Seven years after the discovery that a liquid could be decomposed by the passage of an electric current, it was discovered that solids could be decomposed in the same way. This discovery was made by Humphry Davy when working in his laboratory in the Royal Institution, London, in 1807. He applied the current from his large battery to a piece of potash, and he isolated the metal potassium, which was then seen for the first time. Up to that time, the element had always been locked up in compounds. These discoveries form the basis of the Electro-chemical Industries of to-day.

Now we wish, for a moment, to go back again to a period before the Christian Era, in order to trace the beginning of our knowledge of magnetism. This was the discovery of lodestone, or natural magnet. It is magnetised iron ore found in some parts of the Earth, and first found in Asia Minor, at Magnesia ; hence the name magnet.

It was discovered by the ancients that a piece of lodestone if freely suspended, would always come to rest in a definite position, pointing N. and S., and they made use of this phenomenon by mounting a piece of lodestone in the hand of a small revolving figure, which guided their caravans across the trackless deserts. The compass needle was a natural evolution of this. It was Gilbert who

suggested that the Earth itself is a magnet, and therefore attracts the ends of the compass needle so that it takes up its definite position.

It was discovered by the ancients that the attractive power of lodestone could be *apparently* passed on to pieces of iron by merely stroking them with the lodestone and yet the lodestone lost nothing. We shall see what actually takes place when we consider the theoretical side.

As early as 1731, there were indications that there was a connection between Electricity and Magnetism. I quote the following from the " Philosophical Transactions XXXIX., 1735, page 74.

" A tradesman of Wakefield, having put up a great number of knives and forks in a large box, and having placed the box in the corner of a room, there happened a sudden storm of thunder and lightning by which the corner of the room was damaged, the box split and a good many knives and forks melted. The owner, emptying the box upon the counter where some nails lay, the persons who took up the knives, observed that the knives took up the nails." Lightning had magnetised the steel knives.

In 1751 Franklin succeeded in magnetising a sewing needle by means of the discharge of an electric machine, but the crowning discovery was made in 1820 by a Danish professor, Hans Christian Oersted. This was 20 years after the discovery of the electric current. This discovery was not accidental, as is often supposed, for Oersted announced in 1807 his intention of examining the action of electricity on the magnetic needle. He is said to have been a poor experimenter, but he made a remarkable discovery. During a lecture it occurred to him to try the effect of placing a magnetic needle near a wire in which the electric current was passing. He stopped and tried the experiment. He placed the magnet at right angles to the wire and nothing happened, but after the lecture he tried placing the magnet parallel to the wire, whereupon the magnet turned towards a position at right angles to the wire ; the relationship of magnetism and the electric current was discovered. A very simple discovery but it forms the basis of almost all the practical applications of electricity and is the foundation stone of Electrical Engineering.

It is easy to repeat Oersted's historic experiment. Here we have a magnetic needle and a wire through which we may pass an electric current. We pass the current in one direction and the North pole of the magnetic needle turns towards you. Then we reverse the direction of the current and the North pole of the needle turns away from you. If we place the needle at right angles, as Oersted did at first, of course nothing will happen. We have already placed it in the position to which the electric current would send it.

Within two years of Oersted's discovery a practical galvanometer was invented. In this the magnetic needle is placed within a coil of wire, and the needle may be in a horizontal or in a vertical position; it is a slight variation of Oersted's experiment. The needle moves to left and right as in this model.

It was a simple step from that to the single needle telegraph, but it was not invented until 15 years later (1837). At first there was a crowd of magnets and coils, one to represent each letter in the alphabet, then a system with five needles was adopted, and finally a single needle and code. In the needle telegraph instrument the magnet merely moves to the right hand and to the left hand, but by such means it is easy to signal the Morse Code.

From Oersted's experiment, and from this galvanometer, it will be clear to you that there is a magnetic field surrounding a wire or coil of wire through which there is flowing a current of electricity. We use the word field in the same sense as we speak of a potato field or a turnip field—we merely mean an area containing magnetism.

Here we have a large coil of wire through which we are going to pass a current of electricity from the mains. In this case the magnetic field produced is so great that it is capable of supporting a heavy rod of iron against the force of gravity. You see the iron floating in the air under the attraction of the magnetic field.

So long as the iron is in this magnetic field, the iron is a magnet. You see that it attracts these iron nails. When we withdraw the magnetic field by stopping the electric current in the coil, the iron ceases to be a magnet. And so we have an electro-magnet which

can be made to attract and let go at will. The electro-magnet was invented in 1825 (by Sturgeon).

Here is an ordinary electro-magnet with a fixed core. A piece of soft iron around which is coiled an insulated wire. This simple invention has been of enormous importance. One of its first applications was to telegraphy. Samuel B. Morse, an American artist, was shown one of these electro-magnets by a fellow passenger while crossing the Atlantic. Morse saw at once the possibility of signalling to a distance by such means, but many years passed before he had a practical system with the well-known Morse Code.

The simple Morse sounder became pre-eminent. It is merely a lever, one end of which is pulled down by an electro-magnet, the free end of the lever knocking against two stops and producing by its movements a sound like click-clack. The reason for the Morse sounder's preference over the needle instrument, was that reading the sounds by ear left the eyes free to attend to the writing of the message. The Morse instrument is still in use, and its only rivals are the printing telegraphs.

We have electro-magnets in electric bells, indicators, telephones, and many other devices. A very important application of the electro-magnet is in the dynamo, but before dealing with its evolution we might consider the discovery of electric lighting which was made prior to the invention of the dynamo.

In 1802, Humphry Davy, when working in the Royal Institution of London, discovered that when he took the wires leading from the large battery of 2,000 cells, there was an electric flame produced between the ends of the wires when touched and then separated. The heat of this flame was so great that the ends of the wires were melted. He then fixed a pencil of carbon to the end of each wire, and on separating these he found a beautiful arch or arc of light produced. This was the discovery of electric arc lighting. It was of no practical value so long as the only source of electric current was a primary battery. Davy's discovery forms the basis also of the electric furnace.

The heating effect of a conductor through which an electric current is passing gave rise to the incandescent glow lamp. At first, a fine metal wire was tried, but better success was got by using a filament of carbon; this was heated within a vacuum, so that there could be no combustion. In recent years the carbon filament has been replaced by fine wires of the rarer metals. Incandescent electric lighting did not come into practice until about 1880, it followed the invention of the dynamo.

Prior to the invention of the dynamo, it was discovered that an electric current might be generated by heat. (What I am saying now has no connection with the dynamo). In 1822 it was discovered that when the junction of two dissimilar metals was heated there was a flow of electricity along a conductor joining the ends of this couple of metals. Two metals which acted well were Bismuth and Antimony. When rods of these two substances were joined together, and heat applied to the junction, there was a flow of electricity along a wire joining their free ends. The current was comparatively small, but could be enhanced by using a number of such couples to act together.

These thermo-electric currents have been used for charging accumulators, but the practical application of this discovery has been its use as a sensitive thermometer. The electric current varies with the temperature, and the thermocouple is exceedingly sensitive to heat. You will see its action by this thermo-pile on the table. If we place a match at the end of this funnel, the rise in temperature of thermocouples at the centre of the apparatus will immediately indicate an electric current passing through a galvanometer.

The greater the electric current, the farther does the spot of light move. You will see that even the heat of the hand produces a current. The thermopile is a very sensitive thermometer, and is well known under the name *pyrometer*.

Previous to this discovery, there was only one means of producing an electric current and that was by chemical means in a battery. This thermo-electric discovery provided a second means of generating a current on a small scale, then came the discovery that mechanical

motion could produce electric currents on a grand scale. It came about in this way.

In 1831, Michael Faraday made a far-reaching and historic discovery. He found that when a coil of wire is moved in the neighbourhood of a magnet, there is an electric current produced in the wire. It makes no difference whether it is the coil or the magnet which is moved.

This large coil is now connected to the galvanometer so that any current passing in the coil will move the spot of light. There is no source of current in the circuit, but when we move a magnet in its neighbourhood you see, from the galvanometer, that a current is produced in the coil.

As the coil is a heavy one we have found it more convenient to move the magnet, but the result would be the same if we moved the coil and kept the magnet stationary.

This forms the basis of the dynamo, in which we revolve a coil of wire between the poles of a magnet, and lead out the electric current thus produced. In this we are converting mechanical energy into electrical energy.

The electric motor is merely the converse of the dynamo. If we supply mechanical motion to the dynamo by revolving its coil, we lead out an electric current from the revolving coil. On the other hand, if we supply an electric current and lead it into the stationary coil, we cause the coil to revolve. The dynamo becomes a motor, and in exchange for the electric current we get mechanical motion. The movements of the revolving coil are due to electro-magnetic action; the magnet pulls the coil round because of its surrounding magnetic field.

Faraday also discovered the electro-magnetic induction between two parallel coils of wire, through one of which an electric current is sent. He found that when a current is started in one of the coils it sets up a momentary current in a neighbouring coil, and that an enhanced effect is produced when the current is stopped, the stopping being more sudden than the starting. Nothing happens so long as the current is moving steadily.

Here we have two coils of wire. In the first circuit there is a battery and a key to make and break the circuit in order to start and stop the current. In the second coil there is no source of electricity the circuit is merely connected to a galvanometer. On starting and stopping the electric current in the first coil, you see that we produce a momentary current in the second coil. The making and breaking of the circuit may be performed automatically at a rapid rate, as in a modern induction coil. By increasing the number of turns of wire in the second or secondary coil, the pressure of the current may be increased to very high voltages.

The first attempts at wireless telegraphy were made by using the electro-magnetic induction between two parallel circuits. This system was made use of across the Sound of Mull on one occasion when the cable broke down. Successful experiments were made over longer distances, but the disadvantage was that the length of the parallel wires had to be increased in proportion to the distance between them; the wire used would be sufficient to connect the two places directly.

Another outcome of electro-magnetic induction is seen in the electric telephone. We speak against a disc or diaphragm which forms one side of a box containing loose carbon particles through which an electric current is passing to the line wire. The vibrations of the disc alter the electrical contact of the carbon particles and thus vary the battery current passing through them. This varying current stimulates an electro-magnet in the distant receiver, and the pull of this magnet sets up vibrations in an iron disc or diaphragm causing it to vibrate in sympathy with the speaking diaphragm. Thus the air-waves of speech which we send against the transmitting diaphragm cause the distant receiving diaphragm to set up exactly similar waves, and in this way the speech is reproduced.

The marvel is that the little flat disc can set up the same variety of air-waves or sound-waves for the production of which we require to use our lungs, vocal chords, mouth, tongue, teeth, lips, and nose.

The valve in wireless telephony, now so popular in Broadcasting, has been evolved from the incandescent glow lamp. It was when

experimenting in trying to get rid of the blackening of the globes that Edison discovered what was named the *Edison Effect*—the production of an electric current from the incandescent filament to a metal plate placed within the lamp. This led Professor J. A. Fleming to the discovery of the valve, but this subject I have dealt with in detail in an earlier paper before this Society. (Volume LI. p. 1., 1921).

Turning now to the second part of the subject, the theoretical side, it may be remarked that the only explanation which the ancients could give of the rubbed amber phenomenon was that the amber possessed a soul, and that the rubbing gave it heat and life.

Dr. Wm. Gilbert, who discovered that amber and jet were not the sole possessors of the attractive phenomenon, suggested that electricity was a fluid. Being a physician, and thinking of humours, or kinds of moisture, in the human body, he suggested that objects when rubbed emitted a fluid or effluvium, which created an atmosphere around the objects, and that this accounted for what we now call the electric field surrounding the electrified object. This effluvium was supposed to condense and return to the object when the electric field disappeared.

A hundred years later (1729), when it was discovered that the supposed fluid could be conducted from one object to another, this idea of the returning effluvia had to be abandoned. The words of the discoverer (Stephen Gray) were that " the Electrick vertue of a glass tube may be conveyed to any other Bodies so as to give them the same property of attracting light Bodies as the glass tube does when excited by rubbing : and that this attractive vertue may be carried to bodies that are many feet distant from the tube."

The fact that Electricity could be carried from one object to another led to the idea of the electric fluid being independent of the object itself.

The idea of an electric atmosphere was abandoned later when it was proved that the electricity resided on the surface of the object, and the idea of action at a distance was adopted in its place.

In 1733 it was suggested (Du Fay) that there were two distinct kinds of electricity. It was evident that there were at least two kinds

of electrification. Two objects electrified by contact with an excited glass rod would repel one another. (Like electricities repel one another). Two objects electrified by contact with a resinous rod would also repel one another, but an object electrified by the glass rod would attract an object electrified by a resinous rod. (Unlike electricities attract). It was quite evident that the electrification of the glass rod was different from that of the resinous rod, otherwise they would repel one another. To describe the difference, the glass-electricity was called *vitreous electricity* and the other was called *resinous electricity*.

About twenty years later (1750), Benjamin Franklin suggested that there was only one kind of electricity, and that the two different kinds of electrification were due to an excess and a deficit of a single fluid. He pictured an elastic fluid. By elastic he meant that it was repulsive of its own particles. This single fluid theory was supported by Cavendish, who introduced the notion of electric potential. It was at this time that the terms positive and negative electricities were introduced.

In 1759, in the days when men wore silk stockings, a certain philosopher (Robert Symmer) was in the habit of wearing two pairs, one above the other. On each leg he wore one black and one white stocking. On pulling off one stocking he heard a crackling sound which he attributed to electricity, so he made some experiments. He found that the stockings of the same colour repelled one another, while a black and a white one were attracted to each other. This was really nothing new, but it appeared to him to support a two fluid theory. It is interesting to note that Franklin, who suggested the one fluid theory, sent some apparatus to this philosopher to enable him to test the two fluid theory. It was thought that some of this philosopher's other experiments proved the two fluid theory, which was afterwards generally accepted.

Later there came a reaction from these fluid theories, and it was suggested in our own time that electricity was not a thing *per se*, but merely a condition of things, such as temperature is.

One distinguished scientist, writing in 1892, said :—" Such words as 'electrification' and 'electric' may remain; 'electricity' may gradually have to go."

This theory, that electricity was not an existing thing, but merely a condition of things—*a mode of motion*—was prevalent until the discovery of electrons, which came about in the following manner.

In speaking of vacuum tubes, I have already mentioned Sir Wm. Crooke's radiant matter. He suggested that in addition to solid, liquid, and gaseous, there was a fourth condition within the vacuum tube, which he called *radiant* matter. The idea of radiant matter was not accepted. The discharge in a Crooke's tube became known as *cathode rays*, the discharge being from the negative electrode which is called the cathode.

A Dutch professor (Lenard) succeeded in getting the cathode rays to escape from the vacuum tube by means of a solid aluminium window in the end of the tube, and an English professor (Schuster) made some calculations which gave proof that the cathode rays were composed of particles, but at the time the idea seemed ridiculous. Some years later it was proved that this professor was correct.

When scientists became convinced that the cathode rays were a stream of particles, the Dutch professor's experiment became of great interest. It was evident that the particles which were able to pass through a solid window of aluminium could not be particles of ordinary matter.

Sir J. J. Thomson, of Cambridge, made a special study of the streams of particles within vacuum tubes and succeeded not only in proving that they were particles of negative electricity, but he was able to determine their velocity and their mass. He caused the particles to pass through a magnetic and an electric field produced within a tube, and by measuring the amount of deflections obtained he made many calculations which gave him the velocity of the particles, and the amount of their electric charge.

Hertz had tried the effect of an electric field on the cathode rays, but he got no result. It was only when Thomson used a higher vacuum that he met with success.

It is easy to show the magnetic deflection by a simple experiment with this vacuum tube. You will observe the deflection of the particles whenever this magnet is brought near the tube.

It was in 1897 that Sir J. J. Thomson discovered the individual electrons, and it was found that these negative electrons are identical one to another, no matter from what substance they are taken. It became evident that they are part of the constitution of matter.

An atom could not be made up entirely of negative electrons, for if these electrons were congregated together, they would immediately repel one another; it was evident that there must be an equivalent of positive electricity to attract them and maintain an electric balance. The first picture of the atom was a sphere of positive electricity within which the negative electrons revolved in rings.

Some atoms, are such that they will readily accept the addition of another electron, while other atoms will readily give up or lose an electron. The result is that when these two kinds of atoms are brought into close proximity, an electron leaves one and becomes attached to the other, thus producing a change in the electric balance of the atoms, so that one is electrified positively and the other negatively. This results in an electrical attraction between the atoms. The theory gives us a picturesque view of chemical affinity. It suggests that chemical union is due to electrical attraction.

It is interesting to note that Humphry Davy suggested this in 1826 (two generations earlier). He said "chemical and electrical attraction are produced by the same cause, acting in one case on particles, in the other on masses of matter."

Then again, we picture a certain number of detachable electrons which can be transferred from one object to another, and this constitutes an electric charge. The body acquiring a surplus of negative electrons becomes negatively charged, while the body which has lost the electrons and is left with a surplus of positive electricity becomes positively charged. When a glass rod is rubbed with a silk handkerchief, electrons are transferred by the rubbing, from the glass to the silk, so that the glass rod becomes positively charged, and the silk if insulated from the hand would become negatively charged. If not

insulated, the electrons escape by the body of the experimenter to the earth. A negative charge is an accumulation of electrons—a static condition.

On the other hand, we picture an electric current as a progression of electrons from atom to atom along a conductor. There is a steady stream of drifting electrons under the influence of a chemical battery or a dynamo. The rate of drifting is very slow, but it takes place simultaneously along the whole line, so that the effect at the distant end is immediate. A *direct* current is a steady progression of electrons. An *alternating* current is a to and fro motion of electrons between the atoms without any progression.

Again, we picture magnetism as due to the motion of electrons within the atoms of matter, producing a surrounding magnetic field; i.e., the moving electrons constitute an electric current, and the moving current produces a magnetic field as we saw in the experiment with this large coil.

In a piece of iron each particle of iron is a miniature magnet, but these link up in chains so that they neutralise one another. In an electro-magnet the influence of the surrounding current of electricity causes all these molecular magnets to set themselves with their North poles in one direction, as we saw in Oersted's experiment. This myriad of magnets acting together forms a powerful magnet. The electric current does not produce magnetism in the iron, but merely controls the inherent magnetism of the iron.

Then again, a moving electron disturbs the surrounding aether of space, so that the to and fro motion of electrons produces electro-magnetic waves in the aether. We picture electrons surging to and fro in wireless aerials and setting up those waves which operate the distant receivers.

All light is composed of aether-waves of the same nature but very much shorter in wave length, in other words, waves following closer upon one another's heels than is the case with wireless waves.

The difference in frequency is enormous and is difficult to realise. The waves producing visible light follow each other at the rate of hundreds of billions per second, whereas wireless waves do not even

reach millions per second. The great difference may not be very apparent to you. I believe it is worth while trying to realise the enormity of a billion as compared with a million, and to this end I suggested the following analogy some years ago.

I tried first of all to compare the lengths of lines of a million and a billion dried peas. The lengths were calculated by simple arithmetic, but the results were not very helpful. The line of a million peas only stretched about 4½ miles; the line of a billion peas went round and round the earth, so that it was difficult to visualise. Comparing the weights was not any more helpful. Then the following idea occurred.

Imagine a tank which will hold one million peas, and in the bottom of the tank there is an automatic trap-door which will allow one pea to drop out at the end of each second of time. The tank of a million peas would be emptied in less than 11 days.

Then we imagine a tank holding one billion peas with the same trap-door escapement, and we find that had this experiment been begun in prehistoric times, the tank would not be empty yet, as it would take 30,000 years for the billion peas to escape at the rate of one per second. You may check the analogy by simple arithmetic. It shows that a million is to a billion as 11 days are to 30,000 years.

As already stated, the wave frequency of what we call visible light is hundreds of billions of waves per second; the frequency of those waves used in Broadcasting does not reach millions per second.

It may interest you to see how our knowledge of these electro-magnetic waves has been evolved.

In 1864, Clerk Maxwell predicted the existence of these electric waves from mathematical calculations, but he had no means of detecting their presence. In 1888 Professor Hertz, of Germany, succeeded in detecting and measuring them. In describing his experiment it will be helpful to speak of electrons although they had not been discovered at that time.

What Hertz did was to produce electro-magnetic waves by means of an induction coil and a spark gap. We now picture electrons oscillating to and fro in the spark gap and disturbing the surrounding

aether. The aether waves, thus produced, were reflected by a thick leaden screen on the wall of the laboratory so that the reflected waves might interfere with the direct waves. The overlapping of the waves would produce points of rest or nodes at certain places according to the wave length used.

It is difficult to show the interference of electric waves to an audience, but we have here an analogy from the realm of sound. I can let you hear air waves interfering with one another. When I set up two nearly similar wave lengths in the air they overlap and produce silences or " beats " which are easily recognisable.

The presence or absence of the electric waves was detected by a very simple means. Hertz took a circuit or ring of wire in which a small air-gap was left. When the electro-magnetic waves fell upon this circuit they caused the electrons to surge to and fro in the wire and some of the electrons jumped the air-gap in which they oscillated to and fro producing an electric spark. By moving this detector about, Hertz was able to detect the nodes or points of interference in the waves by the absence of the spark, and from the distances between the nodes he was able to calculate the size of the waves. The waves he was using were found to measure about one foot in length. It was from this experiment that wireless wave-telegraphy was evolved. The waves we now use are of very much greater wave length, each Broadcasting station having a certain wave length given to it.

It is interesting to note that while Hertz detected electric waves (in Germany) in 1888, they were almost discovered by Professor Sylvanus Thompson in London twelve years earlier (1876). Thompson had an induction coil at work in his laboratory and he found that by fixing two door-keys to a block of wood, and leaving only a very small space between the heads of the keys, he was able to get sparks to occur between the keys while he moved about the room, but unfortunately, it never occurred to him that he was detecting electric waves. Speaking of this, Thompson says : " Hertz did not go idly about the room noticing the sparks, but explored the position where the sparks were to be detected."

Referring to our brief consideration of the atoms of matter of which the first picture was a sphere of positive electricity containing revolving negative electrons, it may be observed that vibrations of these revolving electrons would disturb the surrounding aether and produce waves and this is how we picture the production of light. In the sun and all other sources of light there are particles of electricity in a state of vibration and these produce aether waves which affect our eyes, and our photographic plates.

More than 200 years ago a philosopher (Hooke) said : " There is no luminous body, but has the parts of it in motion more or less ; this motion is ' exceeding quick.' "

I must not say more, except that there was next evolved a nuclear theory of the atom and this has proved of great value in explaining different phenomena. We are to have a paper on this subject during the present session by Professor H. Stanley Allen.

It has been impossible to include radio-activity, though it played an important part in the evolution of our ideas of the electrical constitution of matter.

But if the evolution which I have sketched has given you a *bird's eye view* of what has happened, the address will have served its purpose ; you will not fail to realise that in a bird's eye view there are many things of real interest which are not seen, while there is a multitude of interesting detail which is quite invisible.

By Professor ROBERT MARTIN CAVEN, D.Sc., F.I.C.

(Read before the Society, 17th December, 1924).

There are various ways of looking at Nature and trying to arrive at truth. There is the way of the broad outlook, the way in which the mind meditates at leisure on what the eye sees; this leads to a subjective philosophy which may be beautiful, but is liable to be untrue, because it is not tested by all the faculties of man.

There is also the way of intensive study by hand and brain, the way in which facts are sought by every possible means, and theory and philosophy are kept under strict control. This is the way of scientific induction, and it is supposed to lead to objective truth. It is interesting to examine these two ways of human thinking, with the gradations between them; and the development of the atomic theory provides good examples of them both.

To philosophise about the material world may lead to an atomic theory. A building is built of separate stones or bricks; so may it be with the world. Thus Democritus, the Greek, in the fifth century B.C., conceived the world to be made of atoms, which were hard, separate masses; and Lucretius, in a philosophic poem: "De Rerum Natura," taught that all things were composed of atoms in motion; that all change was due to the separation and recombination of atoms; and that liquids being made of atoms the fluidity of water was due to atomic interspaces. Such philosophy, based on superficial observation, was developed by shrewd imagination into the verisimilitude of truth.

In contrast with the ancient theory of atoms was the Aristotelian doctrine of the elements. Aristotle's elements were four: earth, water, air, fire; to which was sometimes added a fifth—an ethereal element, the quintessence. These "elements" were not forms of matter, but qualities; qualities could be changed, and so the elements could be transmuted; this idea was the progenitor of the alchemistic

belief in elemental transmutation. Moreover, the Aristotelian use of the word element persists even now when this word is applied to stormy weather, or when water is said to be the element in which fishes swim.

From the Greeks to Dalton is a leap—a leap across the darkness of the middle ages. Nevertheless there were lights in the darkness, morning stars of the scientific reformation.

Francis Bacon (1561-1626) laid the philosophic foundation of science, and Robert Boyle (1627-1691) was the pioneer of scientific chemistry, and the first chemical philosopher. Said Boyle: "Truly if men were willing to regard the advancement of philosophy more than their own reputations, it were easy to make them sensible that one of the most considerable services they could do the world is to set themselves diligently to make experiments, and collect observations, without attempting to establish theories upon them, before they have taken notice of all the phenomena that are to be solved."

Boyle gave a scientific meaning to the term "element," which according to him was a species of matter, and taught that all substances consisted of minute particles, chemical combination taking place when particles of different kinds of matter were attracted together. Thus he harmonized the separate ideas of elements and atoms, and investigated practically the composition of substances.

The next phase in the development of the subject was concerned with the establishment of the laws of chemical combination, the laws of the composition of substances. Between 1800 and 1808 two French chemists, Berthollet and Proust, engaged in a controversy concerning the question whether the same chemical substance was of invariable composition. Berthollet maintained that chemical processes were dependent on the relative masses of the reacting substances, and that combining proportions thus depended to a certain extent on reacting proportions. For example, when nitrate of mercury was formed by the interaction of nitric acid and mercury, the composition of the product was found to depend on the concentration of the acid used.

Proust, however, maintained the fixity of proportions between the elements in a chemical compound. He said: "Nature never

produces a compound, even through the agency of man, other than balance in hand. Between pole and pole compounds are identical in composition. Their appearance may vary owing to their manner of aggregation, but their properties never . . . . ." The cinnabar of Japan has the same composition as the cinnabar of Spain ; silver chloride is identically the same whether from Peru or Siberia ; in all the world there is but one sodium chloride, one saltpetre, one calcium sulphate, one barium sulphate."

Proust was right ; for Berthollet, in drawing his conclusions, had overlooked the fact that a mixture of compounds may sometimes be formed instead of a single compound. Thus there are two nitrates of mercury, and indefinite mixtures of two definite nitrates, produced by varying conditions, will show on analysis a proportion between mercury and nitrate varying within certain limits.

Thus Proust established the *law of fixed proportions,* the first foundation of the modern atomic theory. Yet Berthollet drew attention to an important principle: the influence of reacting proportions on the extent of a chemical change. Moreover, there is a subtle sense in which the law of fixed proportions is not true, a sense in which it is not true to say that the same compound, although containing the same elements, contains them always united in just the same proportions by weight. The significance of this statement need not be considered here ; but it will become apparent when the subject of isotopes is reached.

John Dalton (1766-1844) was the author of the Atomic Theory of chemical science. Of this man, whose memory all chemists revere, the historian says: " In his modesty Dalton had no thought of acquiring for himself a brilliant position in life, the highest reward for his truly philosophic mind consisting in the elucidation of the truth."

Dalton was much impressed with Newton's law of gravitation, and the corpuscular conception of matter related to it. From stars and planets his mind descended to atoms. After investigating the solubilities of gases in water he concluded that the solubility of a gas depended on the number and relative weight of its ultimate particles, and then added: "An enquiry into the relative weights of the

ultimate particles of bodies is a subject as far as I know entirely new I have lately been prosecuting this inquiry with remarkable success."

Here are some of Dalton's "atomic weights" compared with modern values :—

Element or Compound.	*Dalton's Value.*	*Modern Value.*
Hydrogen, ...	1	1·008
Azot (Nitrogen), ...	4·2	14·
Carbon, ...	4·3	12·
Oxygen, ...	5·5	16·
Gaseous Oxide of Carbon (CO), ...	9·8 (4·3 + 5·5)	
Carbonic Acid (CO_2), ...	15·3 (4·3 + 2 × 5·5)	

Dalton's values differ widely from modern values. He was a crude experimenter, yet inaccuracy does not account for these differences. Dalton's values were really equivalent, not atomic weights ; for in those days there was no means of determining atomic weight magnitudes, because it was not known how many atoms of the various elements combined to form a "compound atom." For instance, in the case of water, it was not known whether one atom of oxygen combined with one atom of hydrogen, or whether the atomic proportions between the elements combining were otherwise ; thus it was not known whether the given atomic weight of oxygen was of the true magnitude, or whether this should be a simple multiple or submultiple of that figure. Dalton's figures are noteworthy because they contain an illustration of the *law of multiple proportions*, which it is to Dalton's credit to have established. Thus of the two oxides of carbon, which we now formulate as CO and CO_2, the latter is seen from Dalton's figures to contain twice as much oxygen to the same amount of carbon as the former.

The laws of fixed and multiple proportions are a sufficient foundation for the atomic theory, which may now be expressed in these two simple statements :

1. Every element is made of homogeneous atoms whose weight is constant ;
2. Chemical compounds are formed by the union of the atoms of different elements in the simplest numerical proportions.

This theory, which seems to resemble the Greek theory, differs from it because :

1. It is founded on ascertained facts, which are the laws of chemical combination.
2. The atoms have relative weights which are determined by chemical analysis—supplemented by other means, i.e., the relations of elements in bulk are regarded as representing relations between their atoms.

In 1835, at the age of 69, Dalton gave a lecture before the Manchester Philosophical Society, in which he presented an elaborate system of nomenclature, symbols, and formulæ, which, although picturesque, are now only of historic interest.

In spite of the warnings of Bacon and Boyle men would theorize; and we cannot blame them; for with the accumulation of atomic weight values came the irresistible desire to discover numerical relations between them.

In 1815 and 1816 there were published anonymously two papers, afterwards known to have been written by an Edinburgh physician named Prout, in which an attempt was made to show, from very imperfect data, that the atomic weights of the elements are whole numbers referred to that of hydrogen as unity. As a conclusion from known facts Prout's hypothesis was unjustified, for the wish was father to the thought; nevertheless it may properly be considered as a flash of philosophic insight, for after many years rich in scientific discovery, chemists have at length arrived at a conclusion but very little removed from the idea of Prout.

The hypothesis was discredited, however, by the accumulation of accurate data regarding atomic weights, particularly through the work of Berzelius; for many of the atomic weights showed values, with reference to $H=1$, which were far removed from whole numbers.

Other relations, however, were soon discovered; relations between the atomic weights and the properties of the elements.

In 1817, and subsequent years, Döbereiner produced his "triads," which were of two kinds, and are exemplified by the following:

$$\begin{cases} \text{Li} & 7 \\ \text{Na} & 23 \\ \text{K} & 39 \end{cases} \qquad \begin{cases} \text{Fe} & 55{\cdot}84 \\ \text{Co} & 58{\cdot}97 \\ \text{Ni} & 58{\cdot}68 \end{cases}$$

The first kind of triad consisted of three elements, all members of one natural family, and so related that the central member occupied a mean position both as regards atomic weight and chemical properties between the extreme members; whilst the second kind consisted of three elements closely related both as regards properties and atomic weights. These relationships have stood the test of time, and are now included in the generalization known as the Periodic Law shortly to be considered.

In 1862, after atomic weights had become more settled, De Chancourtois, a mathematician and geologist, arranged the atomic symbols in a spiral or "*telluric helix*" on a cylinder, there being seven elements in each turn of the spiral. It was then found that related elements occurred on vertical lines, so that Na followed Li, Mg followed Be, and so on.

This achievement did not at the time receive the attention it deserved; but in 1863-4 J. A. R. Newlands developed his "*law of octaves*," by arranging the elements in the following way:

THE LAW OF OCTAVES.

H	1	F	8	Cl	15	Co and Ni	22	Br	29
Li	2	Na	9	K	16	Cu	23	Rb	30
Be	3	Mg	10	Ca	17				
B	4	Al	11	Cr	18				
C	5	Si	12	Ti	19				
N	6	P	13	Mn	20				
O	7	S	14	Fe	21, etc.				

Newlands explained his arrangement thus: "If the elements be arranged in order of their equivalents, with a few slight transpositions as in the accompanying table, it will be observed that elements belonging to the same group usually appear on the same horizontal line. It will also be seen that the numbers of analogous elements generally differ by 7 or some multiple of 7. In other words, the members of the same group stand to each other in the same relation as the extremities of one or more octaves of music."

It is easy to see that this table of Newlands is not only incomplete but also defective; for iron should not be classified with sulphur, and manganese bears no relationship to phosphorus and nitrogen. Nevertheless the "law of octaves" marked an important advance, and

might well have received the approbation instead of the ridicule of contemporary men of science; for, as Sir William Tilden says: " The way was being prepared, but the prophet had not made his appearance, the seer who could look with the eyes of confidence beyond the clouds of uncertainty which obscured all ordinary vision."

The prophet was a Russian: Dmitri Ivanovitsch Mendeléeff (1834-1907), who from 1866 was professor of general chemistry at the University of St. Petersburg. Prince Kropotkin said of Mendeléeff's teaching: " The hall was always crowded with something like 200 students, many of whom, I am afraid, could not follow Mendeléeff; but for the few who could it was a stimulant to the intellect and a lesson in scientific thinking which must have left deep traces in their development, as it did in mine."

In March, 1869, Mendeléeff read before the Russian Chemical Society a paper: " On the Relation of the Properties to the Atomic Weights of the Elements."

" When," said Mendeléeff, " the elements are arranged in vertical columns according to increasing atomic weight, so that the horizontal lines contain analogous elements, again, according to increasing atomic weight, the following arrangement results" :

MENDELÉEFF'S ORIGINAL TABLE.

					Ti = 50	Zr = 90	? =180
					V = 51	Nb = 94	Ta =182
					Cr = 52	Mo = 96	W =186
					Mn = 55	Rh =104·4	Pt =197·4
					Fe = 56	Ru =104·4	Ir =198
				Ni =	Co = 59	Pd =106·6	Os =199
H =1					Cu = 63·4	Ag =108	Hg =200
	Be = 9·4		Mg =24		Zn = 65·2	Cd =112	
	B =11		Al =27·4	(Ga)	? = 68	U =116	Au =197 ?
	C =12		Si =28	(Ge)	? = 70	Sn =118	
	N =14		P =31		As = 75	Sb =122	Bi =210 ?
	O =16		S =32		Se = 79·4	Te =128 ?	
	F =19		Cl =35·5		Br = 80	I =127	
Li =7	Na =23		K =39		Rb = 85·4	Cs =133	Tl =204
			Ca =40		Sr = 87·6	Ba =137	Pb =207
		(Sc)	? =45		Ce = 92		
		?	Er =56		La = 94		
		?	Yt =60		Di = 95		
		?	In =75·6		Th =118		

These are the chief conclusions drawn by Mendeléeff:

1. The elements arranged according to the magnitude of atomic weight show a periodic change of properties;
2. Chemically analogous elements have atomic weights either in agreement (Pt, Ir, Os), or increasing by equal amounts (K, Rb, Cs) (c.f. Döbereiner's two kinds of triads);
3. The arrangement according to atomic weights corresponds with the valencies of the elements, and to a certain extent the difference of chemical behaviour, e.g., Li, Be, B, C, N, O, F;
4. The magnitude of the atomic weight determines the properties of the element;
5. It allows the discovery of many new elements to be foreseen, for example, analogues of Si and Al, with atomic weights between 65 and 75;
6. Some atomic weights will presumably experience a correction.

The *Periodic Law*, according to Mendeléeff, may be stated briefly thus: *The properties of the elements are periodic functions of the atomic weights*; and regarding the law its author said, in 1889: "I now see clearly that Strecker, de Chancourtois, and Newlands, stood foremost in the way towards the discovery of the periodic law, and that they merely wanted the boldness to place the whole question at such a height that its reflection on the facts could be clearly seen." And again: "I consider it well to observe that no law of nature, however general, has been established all at once; its recognition has always been preceded by many presentiments; the establishment of a law, however, does not take place when the first thought of it takes form, or even when its significance is recognized, but only when it has been confirmed by the results of experiment which the man of science must consider as the only proof of the correctness of his conjectures and opinions."

The "boldness" possessed by Mendeléeff, but lacking in his forerunners, is illustrated in conclusions 5 and 6.

In arranging the elements in sequence, Newlands went straight on. Thus he made chromium to follow calcium, because it had a

wrong atomic weight, and manganese similarly to follow titanium, although to classify it with phosphorus is impossible. Mendeléeff could not have put chromium between calcium and titanium, the valency and chemical properties of the element would have forbidden it. Consequently the place after calcium was left unoccupied, until an element should be discovered qualified to fill it, and the place after titanium was found suitably occupied by vanadium, whilst manganese followed chromium a little later. Thus the discovery of new elements was foreseen, and old elements were put in their proper places. That is the result of the " boldness " of Mendeléeff.

Before proceeding further in the story of the periodic law it is necessary in fairness to state that Mendeléeff did not stand alone in its enunciation. Priestley is credited with the discovery of oxygen, but Scheele was its co-discoverer; Darwin is credited with the discovery of natural selection and the elaboration of the modern doctrine of biological evolution, but Wallace must share the glory. Similarly the periodic law is said to be Mendeléeff's, but Lothar Meyer must have some honour too, for a few months after Mendeléeff, he announced independently a similar generalization, and made his own special contribution in the shape of the celebrated atomic volume curve.

The periodic law was not a simple law of nature, of limited and special application like, say, Boyle's law, It was so complex a generalization that it was bound to undergo alteration and amendment with the advance of chemical knowledge. In this it resembled the law of evolution according to Darwin. Now Biologists speak of Darwin and after Darwin; and in a similar way chemists may speak of Mendeléeff and after Mendeléeff. The next stage in the story is after Mendeléeff.

In 1893, and the years following, the inert gases were discovered, and the case of argon created a difficulty with regard to the periodic law, which is apparent when the atomic weights of this element and its neighbours are considered, thus:

K	Ar	Ca
39·10	39·9	40·07

There were here two difficulties; first, there was no room for argon between potassium and calcium where its atomic weight would place it ; second, to place argon before potassium would not only do violence to atomic weight sequence, but also upset the law of octaves, which hitherto had been in harmony with the periodic law. With the discovery of the other inert gases, neon, krypton and xenon, the creation of a new group, the O-group, seemed justified, and it was then found that argon was the only element of the group whose atomic weight was greater than that of the following alkali metal. Thus Group O contained the non-valent elements, just as Group I. contained the univalent elements, and so on.

Then with regard to the difficulty of the atomic weight, it must be remarked that argon did not stand alone, for in the case of cobalt and nickel, as well as in that of tellurium and iodine, the sequence of chemical properties was not that of atomic weight sequence.

These anomalies remained until lately as weaknesses in the periodic system. It was hoped that some day the anomalies would be explained, though there was no probability that the accepted atomic weights of the elements concerned would undergo much alteration. It may be pointed out, however, in anticipation of more recent knowledge, that the accepted order of these elements in the periodic scheme was a tacit recognition that chemical properties take precedence over atomic weight.

The new age in chemistry is the age of radioactivity and of atomic structure. The discoveries of the 20th century have made the atom real, but at the same time complex, and have had a profound influence on the periodic law, an influence which has resulted in the removal of anomalies, and the establishment of the law in a modified form as the most profound generalization regarding the origin and nature of the material universe. Consider some phenomena of radioactivity.

Uranuim (at. wt. 238·17) undergoes a series of radioactive changes and ends with lead with an atomic weight of 206·08.

Thorium (at wt. 232·15) undergoes a series of radioactive changes and ends with lead with an atomic weight of 207·77.

Ordinary lead has an atomic weight of 207·20.

Are there then three (or more) leads? These are all leads, if lead is to be judged by its physical and chemical properties; for they are indistinguishable except for a slight difference of density. So lead is lead, whatever its atomic weight. Yet it is very disturbing not to be able to rely on the atomic weight of an element, for this has been the chemists' sheet-anchor.

Nevertheless the idea of small variations in the weights of the individual atoms of an element is not a new idea; it was suggested by the late Sir William Crookes, who in 1888 said: "It does not necessarily follow that all the atoms shall be absolutely alike among themselves. The atomic weight which we ascribe to yttrium, therefore, merely represents a mean value around which the actual weights of the individual atoms of the element range within certain limits."

Now, whilst ordinary lead has an atomic weight of 207·18, it is only very extraordinary leads indeed which have other atomic weights. It is not likely that these will be met with in ordinary chemical practice, to disturb the analysts' composure. Yet, perhaps, ordinary lead is a mixture of extraordinary leads. It may be calculated that 35 per cent. of 206·08 lead with 65 per cent. of 207·77 lead would yield lead appearing to have an atomic weight of 207·20. Now, the analyst weighs many atoms together, as the banker used to weigh a scoopful of sovereigns, and it no more matters to the analyst than it did to the banker whether all his units weigh precisely alike; for their average weight is always the same.

If Nature had a secret concerning the weights of the individual atoms of her elements, she kept the secret very effectively. As Proust said long ago: "The cinnabar of Japan has the same composition as the cinnabar of Spain." No analyst, unless dealing with radio-active products, as in the above example, has ever detected any deviation from the law of fixed proportions in the compounds he has analysed, for Nature does not show her hand to him, in everyday operations.

Yet at Cambridge, through the labours, first of Sir J. J. Thomson, and afterwards of Dr. F. W. Aston, there has been devised a means

of distinguishing between the atoms of an element when these possess different relative weights. The distinction is seen by the production of a "mass-spectrum," in which different atoms give lines upon a kind of spectrum, the positions of which are determined solely by their masses. Thus Nature's secret has been found out; it is that the atoms of many of her elements differ among themselves by whole units in their weights.

So it has been discovered that there are two neons whose atoms weigh 20 and 22 when O=16. Yet there is only one neon, so far as properties in bulk are concerned, and its atomic weight is 20·2. Evidently this is nearly all Ne^{20} with just a little Ne^{22}. There is only one sodium, Na=23·00, but there are two chlorines: Cl^{35} and Cl^{37}, and ordinary chlorine with the atomic weight of 35·46 is a mixture of these two. Now Proust said in the passage already quoted: "In all the world there is but one sodium chloride." Is that true? It is true as to physical and chemical properties—those gross characteristics with which the chemist is ordinarily concerned. Yet we know now that this NaCl is a mixture of Na^{23} Cl^{35} and Na^{23} Cl^{37}, entities which are ordinarily quite indistinguishable and inseparable.

What is an element? Are Cl^{35} and Cl^{37} two elements or one? That depends upon how an element is defined, but it is now agreed that there are simple and complex elements. Sodium, because it is Na^{23} only, is a simple element, whilst chlorine because it is a mixture of Cl^{35} and Cl^{37}, is a complex element.

Now, evidently Cl^{35} and Cl^{37} can occupy only one place in the periodic table, otherwise there would be confusion, and, besides, their chemical properties are identical. Here is a part of the periodic table brought up to date:

C^{12}	N^{14}	F^{19}
Si^{28} Si^{29}	P^{31}	Cl^{35} Cl^{37}

Atoms of an element having different atomic weights, but necessarily occupying the same place in the periodic system, are called *Isotopes*, and it is interesting to recall that this term was applied by Professor Soddy to the same relationship discovered in connection with phenomena of radioactivity. The application of the term to non-radioactive elements followed the revelations of mass-spectrography.

A remarkable fact appears in the above paragraphs to which attention must now be drawn, a fact intimately connected with modern conceptions of the atom and of the unity of matter. It is the fact that the atomic weights of simple elements are whole numbers when $O=16$, and the related fact that the fractional values of many atomic weights are due to the elements concerned consisting of mixtures of isotopic atoms. It has been seen why $Cl=35{\cdot}46$; the same reason accounts for all fractional atomic weights with the single exception of $H=1{\cdot}008$, which is accounted for otherwise.

Now, the influence of all this on chemical theory is very important. First, it brings back Prout's hypothesis in a slightly modified form.

The atomic weights of the simple elements are all whole numbers within a very close approximation, because the elements themselves are genetically connected; they have a common origin, they are built up, all of them, of only two kinds of still smaller atoms, which are electrical in nature. These electrical atoms are called *protons* and *electrons*; a proton is an atom or natural unit of positive electricity, an electron an atom or natural unit of negative electricity. It is the protons which are the cause of nearly all the mass of an atom, for the electrons have very little mass. A neutral atom is necessarily composed of an equal number of protons and electrons; all the protons, and some of the electrons, are at the centre of the atom, in its nucleus, the rest of the electrons are contained, and appear to revolve in successive shells outside the nucleus. Thus an atom is like the solar system, with the nucleus as sun and revolving electrons as planets.

All this is now becoming a familiar tale. How the tale has been unravelled is too long to tell, but its bearing upon the atomic theory and the periodic system may be briefly indicated.

Every atom consists of a nucleus with surrounding electrons. The nucleus has a charge of positive electricity which is the difference between the number of its protons (+) and electrons (—). This charge is balanced in a neutral atom by a number of electrons numerically equal to it. So each atom has a characteristic number which is expressed in two ways, (1) by the positive charge on the nucleus, (2) by the negative charge, i.e., the number of electrons outside the nucleus. The periodic system shows the progression of the elements according to these numbers, the *atomic numbers*, beginning with hydrogen and ending with uranium ; and the system is periodic because the peripheral electrons in the atoms of successive elements are arranged in a series of shells, so that when one shell is completed another begins. De Chancourtois arranged the elements in a spiral, and when one turn of the spiral was completed another was begun with an element analogous to the first. The successive turns of the spiral correspond with successive shells of electrons in the atoms. The secret of the periodic law in all the forms in which it has been presented from time to time, is contained in the successive shells of electrons within the atoms of matter, from the lightest to the heaviest of them.

It is noteworthy that the atomic number of an element, which is numerically equal to the difference between the numbers of protons and electrons in the nuclei of its atoms, is not dependent on the actual number of protons. If a proton is added to the nucleus the atomic number is not altered, provided an electron is also added to neutralize it. Thus two atoms can have the same atomic number but different atomic weights. Such atoms are isotopes, e.g., Cl^{35} and Cl^{37}. It is atomic number, not atomic weight, which determines chemical properties. So the periodic law needs redefinition.

The periodic law according to Mendeléeff was :

The properties of the elements are periodic functions of the atomic weights ; it now becomes :

The properties of the elements are periodic functions of the atomic numbers.

So atomic weight becomes a secondary consideration; the tiresome decimals in the atomic weight table, whilst still necessary for analytical purposes, have no more significance than the fact that mixtures of isotopes produce them, whilst the anomalies of atomic weight sequence, as with argon and potassium, or tellurium and iodine, are seen to be due to the predominance of heavier isotopes which cause the atomic weight of the heavier element to exceed that of the element which naturally follows it.

One other consideration remains. We have spoken of atomic number. What is the atomic number of a particular element, and how many elements are there in the full gamut of the elements from hydrogen to uranium?

The X-ray spectra mapped by Moseley supply the answer. The succession of these spectra makes a picture like a stairway, and in a broken stairway you may see the missing steps.

From hydrogen to uranium there are 92 steps—92 elements, and only 5 of these are missing, only 5 remain to be discovered now.

Newlands tried to number the elements, Mendeléeff tried to leave blank spaces for all the missing elements, but could not say how many rare earth metals there might be; Werner made a guess at the number of these and was only one unit wrong; now the roll-call is complete so far as numbers are concerned, and the periodic system at length seems perfected. The accompanying figure (p. 80) shows this great generalisation in its final form.

The conclusion of the whole matter is that atoms are as real as but no more solid than the solar system.

Long ago Wordsworth wrote:

> "To the solid ground of Nature
> Trusts the mind which builds for aye."

In one sense the solid ground is gone, but we may trust Nature nevertheless. Nature never betrayed the mind that trusted her. The chemist has long dreamed of an underlying unity amid all the diversity. What does evolution signify but this? The dream is true, unity is revealed, and it reaches through the Universie.

PERIODIC TABLE OF THE ELEMENTS—ACCORDING TO ATOMIC NUMBERS.

No. of Elements																																	
$2 = 2\,[1^2]$	**1**																H 1	He 2															
$8 = 2\,[2^2]$	**2**													Li 3	Be 4	B 5	C 6	N 7	O 8	F 9	Ne 10												
$8 = 2\,[2^2]$	**3**													Na 11	Mg 12	Al 13	Si 14	P 15	S 16	Cl 17	Ar 18												
$18 = 2\,[3^2]$	**4**								K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36							
$18 = 2\,[3^2]$	**5**								Rb 37	Sr 38	Yt 39	Zr 40	Nb 41	Mo 42	— 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54							
$32 = 2\,[4^2]$	**6**	Cs 55	Ba 56	La 57	Ce 58	Pr 59	Nd 60	— 61	Sa 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Hf 72	Ta 73	W 74	— 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	— 85	Rd 86
Incomplete		— 87	Ra 88	Ac 89	Th 90	Bv 91	U 92																										

By F. F. P. BISACRE, O.B.E., M.A., B.Sc., A.M.Inst.C.E.

(*Read before the Society, 11th March,* 1925).

It was with much misgiving that I accepted the President's invitation to address the Society to-night upon the subject of "Railway Electrification round Glasgow." But on reflection, I began to see that there was something to be said for an address by a layman upon a subject of this kind. He is not a railway man, nor a tramways official, nor a practising engineer, but is just a member of the public. It matters not one whit to him, professionally, whether one system of transport or another is adopted in Glasgow. He can study the problem as a whole without considering whether a particular Power Station belongs to the Corporation of Glasgow or to somebody else.

The Importance of Public Health.—It is not our business to discuss the general question of public health. I take it for granted that a community must possess health in a high degree. Ill-health is dearly bought, at any price.

On the authority of Sir George Newman, Chief Medical Officer of the Ministry of Health[i.] we may take it that the following are the more important factors affecting public health :—

(1) Climate, including sunlight, (2) Housing, (3) The food supply, (4) Public cleanliness, (5) Plenty of genuine work, (6) Enough health-giving play.

(i.) Annual Report (1923), England and Wales, *Glasgow Herald*, August 19th, 1924.

Judged by these standards, how do we in Glasgow stand to-day? This is a wet, northern city, where grey skies and sun-less days are only too familiar.

As to housing, I will just read a remark made by the Scottish Board of Health's Commissioner, who held the local enquiry into the Glasgow (Cowcaddens, etc.) Improvements Scheme.[ii.]

> "I have read," he says, "many descriptions of slum conditions, and I am familiar with those conditions as they obtain to-day in various parts of Scotland, but any description which I have ever read and any slum property which I have hitherto visited has made nothing like the impression which these Glasgow slums have left upon my mind."

The man who made this remark was no Southerner, unfamiliar with local conditions, but a Scotsman, and the remark was made after a very full enquiry into the actual conditions.

The evil effects of unemployment, and of the dole, are dealt with in the same Report.[ii.] The Board refers to:—

> "The effect which continued unemployment threatens to have on the young people who are growing up in the abnormal and unhealthy atmosphere of a world that makes no call on their capacities for service."

What of healthy play? The answer is—watching (not playing) professional football matches, street-betting, cinema-going, with an occasional diversion on Glasgow Green on Saturday or Sunday.

Congestion of the Population.—A factor in bringing about this state of things is clearly the massing of the population in the city. This is a disease from which Glasgow does not alone suffer. It is a present-day social disease of Europe in general and of Scotland, especially.

[ii.] It is given in the Fifth Annual Report, Scottish Board of Health (1923).

Table I.

DENSITY OF POPULATION.

City.	*Date*	*Population.*	*Area (Acres).*	*Persons per Acre.*
GLASGOW[1] ...	1921	1,034,069	19,183	53·9
LONDON[2] ...				
County[(a)] ...	1921	4,483,249	74,850	59·9
Greater[(b)] ...	"	7,476,168	443,530	16·9
NEW YORK[3] ...				
Greater, ...	1924	6,015,104	201,446	29·9
EDINBURGH[4] ...				
Before 1920[(a)] ...	1911	320,318	10,877	29·4
After 1920[(b)] ...	1921	420,281	32,402	13·0
MANCHESTER[5]	1921	730,551	21,690	33·7
MELBOURNE[6] ...				
Greater, ...	1921	816,800	70,000	11·7
SYDNEY[7] ...				
City[(a)]	1921	110,200	3,327	33·1
Greater[(b)] ...	"	906,320	95,259	9·5
CAPE TOWN[8] ...				
Greater, ...	1921	207,000	37,700	5·5

SOURCES OF INFORMATION.

[1] *Pop.* Census Returns, 1921. *Ar.* Corporation of Glasgow Diary, 1925.
[2](a) *Pop.* and *Ar.* Census Returns, 1921.
(b) *Pop.* and *Ar.* Municipal Year Book, 1924.
[3] *Pop.* and *Ar.* "The World Almanac," 1914.
[4](a) *Pop.* Census Returns, 1911. *Ar.* Oliver & Boyd's "Edinburgh Almanac," 1925. 1911 chosen as being Census Year immediately preceding extension of boundaries.
(b) *Pop.* Census Returns, 1921. *Ar.* Oliver & Boyd's "Edinburgh Almanac," 1925.
[5] *Pop.* and *Ar.* Census Returns, 1921.
[6] *Pop.* "Australian Year Book," 1923. *Ar.* Doubtful, but not less than 70,000.
[7](a) *Pop.* "N.S.W. Year Book," 1922. *Ar.* "N.S.W. Year Book," 1922.
(b) *Pop.* "Australian Year Book," 1923. *Ar.* "Australian Year Book," 1923.
[8] *Pop.* "South African Year Book," 1910/-21. *Ar.* "Encyclopedia Britannica," Supplementary Volume, 30.

Table I. shows the populations of a few cities, with the corresponding administrative areas. The fifth column shows the density of the population in persons per acre. The figures are the most recent I can find. The table shows that leaving the heart of London out of consideration—just as we leave the heart of Glasgow and New York out of consideration—the density of population in Glasgow is over 50% higher than the figures for any other of the cities in the table. The contrast with the colonial cities is most marked. Sydney, with a population a little less than Glasgow, covers an area nearly five times the size of Glasgow, while Cape Town, with a population one-fifth of Glasgow, covers an area of nearly twice that of Glasgow. It is quite evident that though the colonial populations are somewhat smaller than that of Glasgow they are spread over a very much greater area, and in order to do this, adequate transport is and must be provided in these cities. Other things being equal, then, we should expect that the transport provided for a given population would be better the more the population is spread out; conversely, a very high concentration of population will accompany bad transport facilities. This, we shall see later, proves to be the case in Glasgow.

Fifty years ago people had to squeeze into large cities because they had to live near their work. Glasgow became prosperous, work grew, people flocked in to do the work and tenements sprang up to house them. Then came slums, high infant mortality, and all the evils of overcrowding.

Fifty years ago there was *good reason* for workers to crowd together in large towns and some justification for high, barrack-like tenements. The art of transport was not sufficiently developed to allow the people to live at a distance from their work; on the other hand, labour and building materials were cheap, land fairly dear, so that the natural line of development was to have high tenements and congested districts. To-day perhaps every one of these reasons has gone. Rapid transit can be had and that cheaply; land is comparatively cheap, while tenement building—as opposed to building in one or two storeys—is dear. The obvious policy, then, is to spread the population out over a larger area.

What can Railway Electrification do to help matters :—The problem we are concerned with is: "What can Railway Electrification do to improve the Public Health and to relieve this congestion, and, in particular, to give us more sunlight, pure food, especially milk, and better housing?" The answer obviously is that, if we wish, we can abolish smoky steam trains entirely within the city and replace them by electrically-hauled long distance trains and clean, quick, electric local trains. It may be argued that this would not do much good. We can, at least, do everything that seems to be a step in the right direction. One such step is, I submit, to *allow* the sun to shine in the city when he chooses to do so, and to do this we should prevent smoke as far as we can. This is one way in which Railway Electrification can help. Before leaving this point, I should like to remind you of what has been done in New York, Three large railways—the New York Central; the New York, Newhaven and Hartford; and the Pennsylvania Railways—have large termini in New York, and I understand that steam locomotives are to be excluded altogether from the City of New York in five years' time.[iii.]

Electrification can provide a *swift* and *clean* form of transport. Speed and cleanliness are specially important for the transport of milk and perishable food.

But it is in helping to solve the housing problem that suburban railway electrification can do yeoman service. By providing a swift, clean, convenient and cheap means of transport, the Railway Companies can take the people to their work, from the country, in the morning—and back to the country, in the evening—*without undue loss of time or energy. The housing problem has, therefore, entirely changed.* It is no longer a problem of housing say a million people on an area of 20,000 acres. It is the problem of housing say $1\frac{1}{4}$ million of people on an area of, say, 200,000 acres. More space becomes available, wider streets can be made and lower houses built, so that the sun can shine into the streets, even during the darkest winter months. It is chiefly for these reasons that suburban electric railways

(iii.) Bailie W. B. Smith spoke after the lecture and said that a similar regulation was proposed for Glasgow. It would come up again in connection with the City Bill next autumn.

play such an important part in solving the problem of constructing large healthy industrial towns. Electric railways—and let us add motor buses—are a recent development. There were no regular electric railways before 1890. It is a matter of history that large towns have electrified their suburban railways; I need only mention London, Newcastle, Liverpool, Manchester, at home—and Paris, Berlin, New York, Melbourne, Buenos Ayres, Bombay, Johannesburg, Cape Town, Durban, and many other places, abroad.

How does Glasgow stand? We have trams, the subway, and a meagre service of taxi-cabs which charge very high rates. We have, as well, our horse-drawn cabs. We have some experimental motor buses—a step in the right direction—but no electric railways.[iv.]

There is no need for me to enlarge upon the congestion of our streets—a congestion that is admittedly due, almost entirely, to the presence of the tramcars. I propose to put on the screen some photographs of Glasgow streets which tell the story more eloquently than any words or figures of mine.

(Five lantern slides showing the present congestion were put on the screen.

I should like to read a passage from a recent report of the City Constable, in this connection.[v.]

"The present congestion is of such a nature as to endanger the safety of the citizens and hamper industrial and other transport.

"The chief causes of the traffic congestion are (1) the unequal proportion of the street space claimed for the use of tramcars; (2) vehicles standing on streets for the purpose of loading or unloading goods, or waiting for passengers; (3) street traders with barrows, and flower sellers.

"The combined factors of the tram tracks being in the centre of the streets, and of the cars necessarily having to run thereon without any possibility of deviation by inclining to the right or left, with insufficient width of streets for the normal business traffic, and

(iv.) There are about 160 motor vehicles licensed by the Magistrates as taxicabs in Glasgow, as compared with 7,634 taxicabs in London—to say nothing of London's 5,117 motor buses. The fares in Glasgow are 1/6 for the first mile, plus 4½d. for each additional quarter mile. In London it is 1/- per mile within a six-mile radius, and 1/6 per mile for reasonable distances outside, which is usually assumed to be about ten miles from Charing Cross.

(v.) Extract from City Constable's Report to the Magistrates, dated 13th April, 1923.

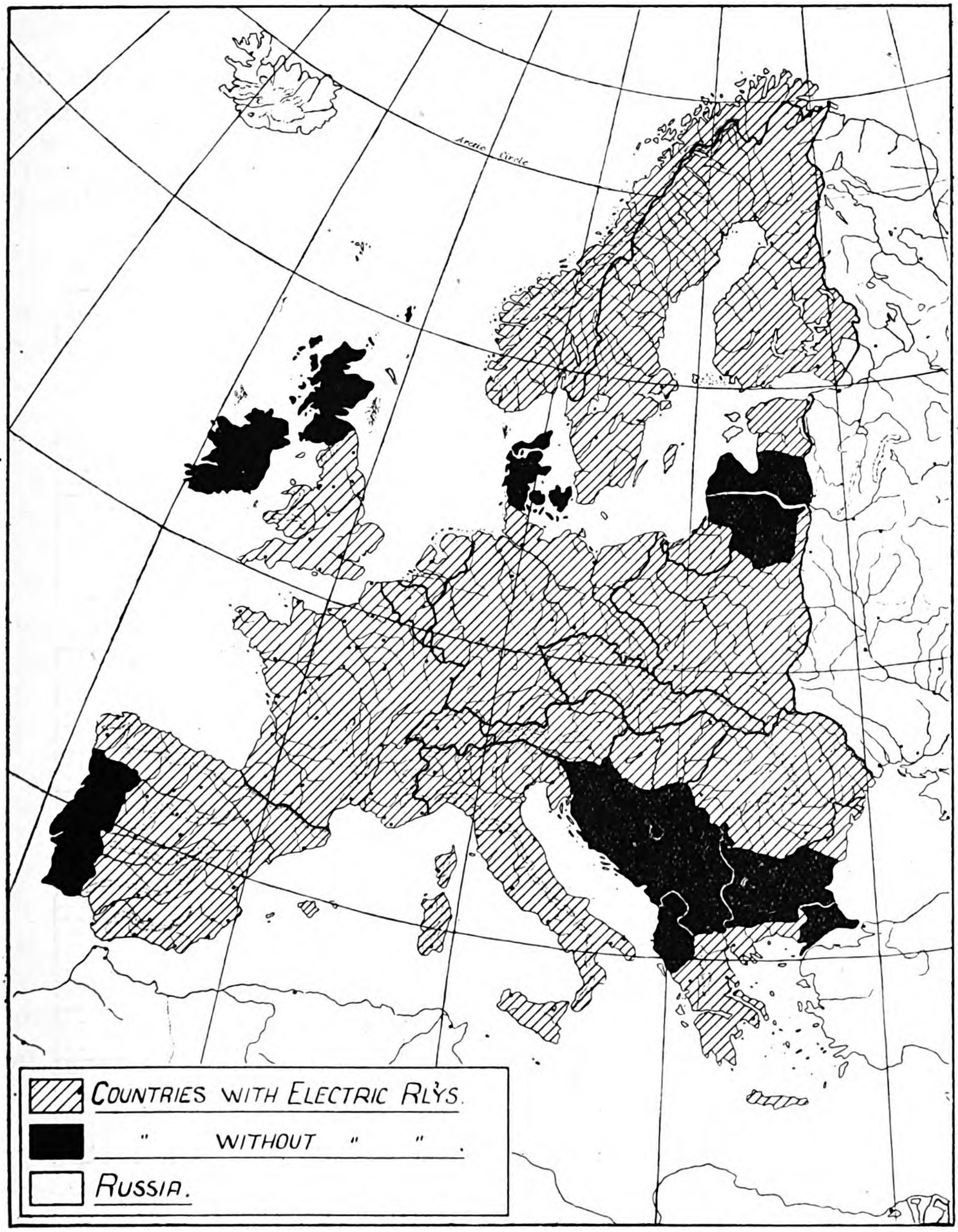

Arctic Circle
COUNTRIES WITH ELECTRIC RLYS.
" WITHOUT " " .
RUSSIA.

FIGURE I.

mixed and varying speeds of ordinary traffic, all contribute to the obstruction and congestion of traffic."

Growth of Electric Railways in other Countries.—It may be interesting to see what progress has been made in other Countries in railway electrification.

Figure I. is a map of Europe showing the Countries of Europe with and without Electric Railways.

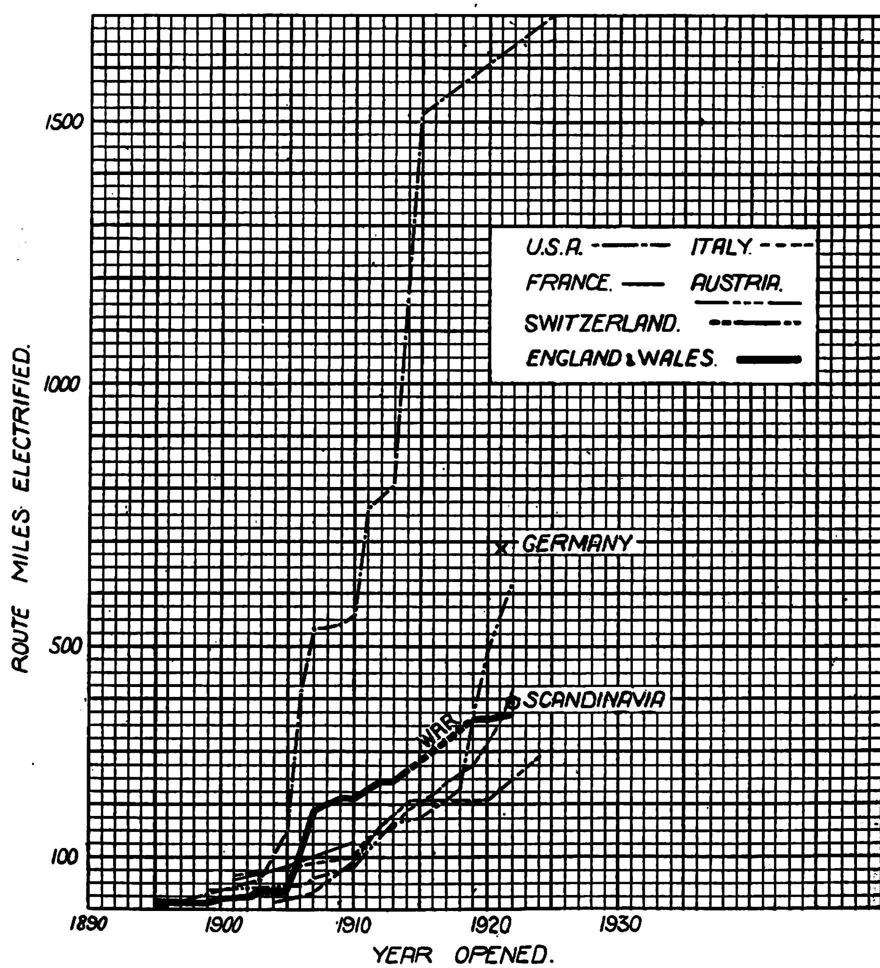


FIGURE II.

Figure II. is a set of curves showing the length of railway *route* that is now run electrically in different countries. This curve has been prepared from the summary of the railway electrification of the world which was published by Professor S. Parker Smith, of the Royal Technical College, in the Journal, "World Power." He has kindly given me permission to make these curves from his figures.[vi.]

It will be seen from this diagram that progress has been extraordinarily rapid in Europe and the U.S.A. At least three of the Railway Companies in England, before the amalgamation took place, had plans completely developed for electrifying the *whole* of their systems.

Why Suburban Electric Railways can give improved transport as compared with Suburban Steam Railways.— Why are electric railways *better* than steam railways? The points that go to make a good service of suburban trains are cleanliness, frequency, speed, and cheapness. In every one of these respects the electric suburban train is easily ahead of the steam train, and as this claim is really the key to the whole position, I am going to spend a little time in giving you my reasons for making it.

The first point I should like to make is this:—

(1) *Steam railway lines can be and are used by electric trains.*

The electrification of railways does not of necessity call for tubes.

The existing lines have to be converted to electrification, that is, an electric conductor is provided and the ordinary rails are "bonded," as it is called. The bonding of the running rails is done so that a current can run along them. The electric conductor may be a third rail, as on the District Railway in London, the lines round Newcastle-on-Tyne, etc., or an overhead conductor as on the Brighton Railway and the Suburban Railways of Melbourne.

(vi.) The latest information on the U.S.A. curve was given to me recently by the General Electric Co. of New York. "B. E. A. M. A." September, 1923, November, 1924; "World Power" April, 1924, June, 1924, November, 1924.

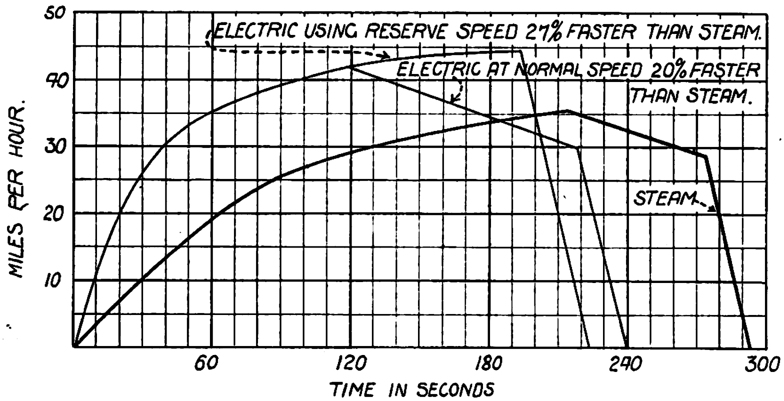
The railway routes are obviously the proper places for high speed traffic—not the roads; on the other hand, round large towns the railways are often badly curved and have heavy gradients. We all know to our cost that a stopping steam-train is a painfully slow vehicle. On a bad curve an electric train must not run faster than a steam train, and heavy gradients reduce its speed. How then is it possible for an electric train to give us a higher speed than a steam train? This is the answer—

(2) *The electric train picks up speed much more quickly than the steam train does.*

The suburban electric train is, as a rule, a *multiple-unit* train, i.e., each train is made up of 1, 2, 3 or 4 *units,* each of two coaches. One is a *motor-coach* and the other a *trailer-coach.*

Every axle of the motor coach is driven by a motor, in modern equipments, hence rather more than one half of the total weight of the train is used for getting a grip of the rails. As a rule, in the steam train only two axles, in the whole train, are driven. Now, it is an elementary law of mechanics that the maximum pull that we can get on to a vehicle, by turning the wheels, is limited—because if we turn the wheels too hard they will slip. The question of what pull we can get on to a railway carriage depends therefore on the roughness of the wheels and of the track, and on the load carried by the driving wheels. Of course the weight on non-driving wheels does not help us since these wheels are not being turned. The pull we can get is from $\frac{1}{4}$ to $\frac{1}{5}$ of the weight on the driving axles, hence with an electric train weighing, say, 200 tons, we can get a pull of $\frac{1}{5}$ of 100, i.e., 20 tons; in a steam train we could only get a pull of about 10 tons, because a suburban steam locomotive weighs about 90 tons, of which only 50 tons are carried by the driving wheels. The pull is therefore $\frac{1}{5}$ of 50, i.e., 10 tons. It is evident that a train will speed up much more quickly if we can apply a pull of 20 tons instead of 10 tons. It is *by making use of this quicker start* that the speed of suburban *stopping* services can be greatly increased.

Figure III. shows the difference



TYPICAL RUN CURVES — 2.0 MILES.
SPEED CURVES FOR STEAM AND MULTIPLE-UNIT TRAINS.

FIGURE III.

between the motion of a train drawn by electricity and the motion of a train drawn by steam. The distance covered between the start and the stop is two miles. The maximum speed allowed is 45 miles per hour, and the electric train will do the trip in 240 seconds (and 225 seconds if required), whereas the steam train takes 293 seconds. The average speed over the run is therefore 30 miles per hour with the electric train and 25 miles per hour with the steam train, an improvement of speed of 20%. The quick start with the electric train leads to high economy in fuel.

(3) One objection often put forward against electric trains in Scotland is that the lines are hilly and "therefore" unsuitable. This objection is groundless for the *electric train is specially well suited to lines having heavy gradients*. The reason for this is again the specially heavy pull that electric traction gives, as compared with steam. A train, driven electrically, can work comfortably on a gradient which would *stop it dead* if pulled by a steam engine. Many of our lines make detours to avoid heavy gradients. These detours could be cut out altogether with electric haulage at a great saving of money and time.

(4) We now have to consider how the electricity is to be supplied to the train. A third rail or some form of overhead construction is

provided on the track. How is this electric equipment to be made "alive"? The majority of suburban electric trains use what is called *direct-current* on the trains. This current is the same kind as one gets from an ordinary accumulator.

We must therefore provide a supply of direct-current to the trains, and this is done by means of a "third rail" or an overhead conductor, depending on whether low-pressure or high-pressure electric current is used. The higher the pressure, the smaller the currents will be, and vice versa. Heavy currents need thick conductors and thick conductors means much copper, and copper is a costly metal. Further, for technical reasons, a high-pressure currrent passes from place to place with less waste of coal than a low-pressure one. Hence it is quite natural that electrical engineers have consistently increased the pressure of the current going to the trains, just as their brother mechanical engineers have pushed up boiler pressures from 3 lbs. per square inch in 1830 to 1,000 lbs. per square inch to-day in America. The pressures used on the London direct-current railways are about 600 volts. In Newcastle 800 volts is used. The conductor carrying the current to the trains is a "third rail," which is usually placed on one side of one of the running rails. To prevent sparking between this "live-rail" and the running rails, the live-rail must be kept clear of the running rail by about 1 inch per 100 volts. If instead of 800 volts, 1,500 volts were proposed, the clearance would rise from 8 ins. on this rough rule to 15 ins., and such a clearance cannot always be got. An overhead wire is then used, e.g., on the Melbourne Suburban Railways. This change merely shifts the "pinching boot" from one foot to the other. A clearance must be found for this wire. This is easy enough in the open country, but there may be difficulties at bridges and in tunnels. The upshot of it all is that for these, and other technical reasons, engineers use the highest pressure they can. A standard pressure of 1,500 volts is recommended in the Report of the Advisory Committee on Electrification to the Ministry of Transport 1921. It therefore comes to this—there must be some form of conductor, either an overhead wire or a third-rail, over or alongside the existing running rails, to carry direct current to the trains.

So far all our current has been direct-current. This current is used because direct-current motors *and their accessories* are much cheaper, lighter and stronger than the kind of single-phase alternating current motor that would have to be used. But—here comes the usual engineering dilemma—alternating current is much the better kind of current to generate in large quantities. Nearly all large generating stations produce alternating current, and there are good reasons for this. Perhaps the chief of these reasons is that the really high pressures are more easily manipulated when the current is alternating; and, if the power is to be transmitted long distances, a *really* high pressure of transmission (20,000 volts or more) *must* be used.

The difficulty is overcome by the use of machinery which converts alternating current into direct-current, much as gearing converts the high speed of the turbine into the low speed of the propeller in a turbine-driven ship. The machine is called a *rotary converter,* though sometimes motor-generators are used. It is fed with alternating current and delivers direct current. These machines are housed in sub-stations scattered about at different points on the railway system. In new plants these sub-stations would be controlled electrically from a common centre of control. No sub-station attendance is needed, if this is done, beyond a visit, now and again, to see that oil cups are full, brushes in order, and so on. Another method used is to work the automatic sub-station by means of relays, the principle being that pressure is always kept on the line. If anything happens to a motor generator set, due to hot bearings or any other cause, it is automatically shut down and another automatically started up. If, on the other hand, the sub-station is cut off the line by the circuit breaker coming out, it is replaced automatically so many times and—if it does not clear the fault—it remains off, and so on. The manual control, in this case, is limited to a small switch in the station-master's office by which he puts the sub-station into its operating position or not; if the switch is on, then the sub-station does the rest.

High-pressure alternating current electricity is supplied to these sub-stations by means of a transmission system which may consist of cables, with overhead lines in country districts. This current is exactly the same kind as is generated in nearly all large power stations, e.g., Dalmarnock, Clydebank, and so on. The whole story can be read in Figure IV. The purely " Electric Railway " plant is:—

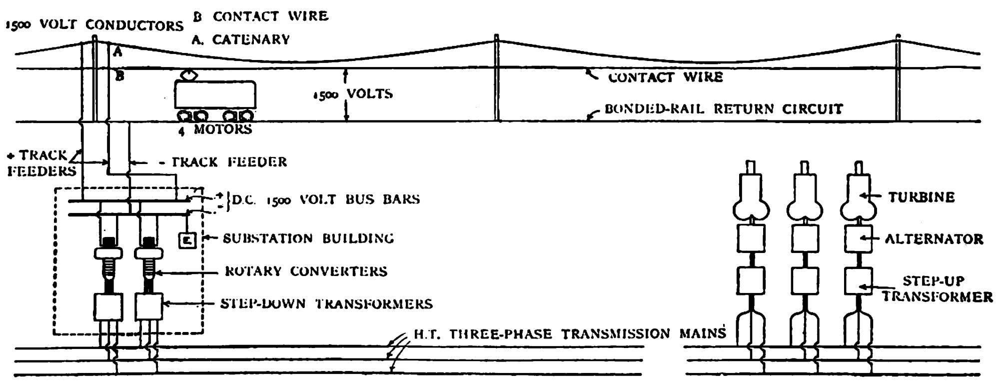


FIGURE IV.

1. Sub-stations and Rotary Converter Plant.
2. Track Construction.
3. Motor-driven Rolling Stock.

The last item—rolling stock—is a costly one ;but rolling stock must, in any case, be provided (*see footnote page* 106). It is the *electrical equipment of it* that is the new feature. The electrical scheme is, therefore, chargeable with the *electrical* equipment of the rolling stock only.

A great deal of essential construction demands unskilled labour, e.g., digging trenches for cables, labourers' work in connection with sub-station buildings, and so on. To give work of this kind to the unemployed is obviously more profitable to the community and to the unemployed themselves than to give doles. Hence the Government is prepared to give financial assistance (as it is doing in London) to those carrying out electrification schemes.

The Glasgow Suburban Railways.—I propose now to deal with the Glasgow situation in a little more detail. Before doing so, I

had better say that the material I have had at my command consists of the published Railway Time-tables, the Blue Book of Railway Returns for 1923, issued by the Ministry of Transport, and the Ordnance Maps of the district.

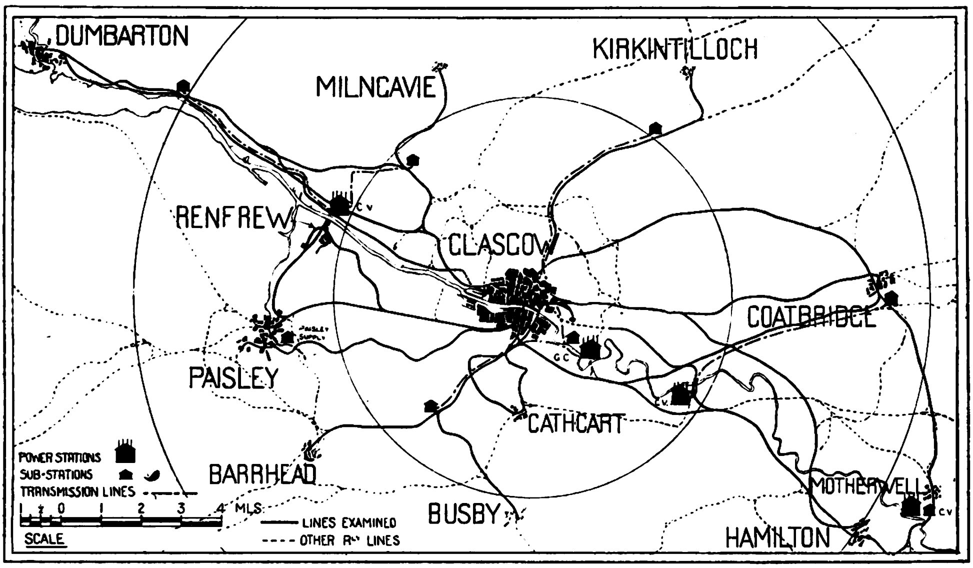


FIGURE V.

Figure V. is a map of the railways round Glasgow. The circles are of 5 and 10 miles respectively. I shall speak only of the heavy lines. The route mileage of these heavy lines comes out at about 148 miles. In arriving at this route mileage I have considered every route into the Glasgow termini as a separate one. For instance, in coming into the Central Station, the high level trains come over the Bridge, which is very heavily tracked. I have counted every one of the separate routes converging on to this bridge as a separate route, so that, in effect, the route mileage stated is the route mileage of double track. Multiplying this by 2.2 we get 326 as the approximate mileage of single track, including the usual proportion of sidings. The true figure may be a little more; it may be a little less, but I do not think it will differ very greatly from 326 miles. However, this is just one of the points on which the Railway Companies alone really have

the facts. The Time-table shows that the passenger train mileage over these lines amounts to about two million train miles per annum. This figure appears to me to be very small for a city of the size of Glasgow, so I have specially calculated the figures given in Table II.(vii.)

Table II.

TRAIN FACILITIES, 1925.

City.	*Train Miles per Annum per Person.*
Glasgow, ...	1·25
Manchester, ...	1·43
Newcastle, ...	1·60
Cape Town, ...	3·34

If the train service in Glasgow were in the same proportion to the population as the service in Cape Town is, we should be provided with about six million train miles per annum—that is, just about three times the service we have. I may have underestimated the Glasgow service—I hope very much that I have—for, if I have, it will be even more advantageous to work the service electrically than my subsequent figures show. The cause of the low figure for Glasgow is more or less obvious. The city is highly congested and the people use the trams instead of the trains. One of the objects of electrification would be to increase the railway traffic by providing a better service of trains (*see footnote, page* 105). We must, therefore, figure on more than two million train-miles. But—and this is an important " but "—the size of electric trains can be adjusted to suit the traffic, 2-coach trains during light hours, 6 or 8-coach trains during heavy hours; whereas steam trains cannot be so easily broken up.(viii.)

(vii.) The figures are based on the official time-tables and statistics of population.

(viii.) In other words, the ratio of " seat-miles paid for " to " seat-miles run " is much higher with electric than with steam traction because of the flexibility of the multiple-unit system.

This is because each 2-coach unit of the electric train is provided with its own motive power and can be driven equally well from either end. Splitting up—without heavy shunting—is therefore easy. It is assumed that a fair electric service to begin with would be about 2,600,000 train miles per annum of 4-coach trains as an average figure, making about 10½ million coach-miles per annum. Such a service *could* be run with an annual consumption of electrical energy of 43 million units per annum, corresponding to a maximum demand of about 15,000 K.W. These figures are probably high, and are therefore against electrification in point of cost. They are based upon actual figures obtained on railways where the length of run is distinctly shorter than on the railways round Glasgow, and the shorter the run, the higher is the energy consumption for a given schedule-speed. On the other hand, the Glasgow routes are somewhat hilly. We may therefore take it that these figures are an upper limit for the service stated. This power would have to be supplied from somewhere. Glasgow is very well supplied with power stations, and some of these, such as Yoker, Dalmarnock, Cambuslang, and Motherwell are very well placed for giving a railway supply. Of course, it is not for me to say whether they would or could give such a supply. I am simply saying that if they would and could, the power stations are well placed for giving such a supply.

The track pressure used would probably be the standard one—1,500 volts D.C. I assume this.

The map (Figure V.) shows roughly the number of sub-stations that would be needed for a 1,500 volt scheme. There are eight of them scattered about the system. To feed these sub-stations, high tension three-core cables or overhead transmission lines would be needed. These lines are shown on the map. Sometimes these lines can be run up very cheaply on extensions of the track structures. On the other hand, if cables were needed—and there is no doubt that there would be a good deal of cable work in a town like Glasgow—the transmission lines would become costly, for the cable is not only very expensive in itself, but there is the labour of excavating and reinstating the ground.

With this information it is possible to hazard a rough estimate of the capital cost of the *electrical* equipment. I have arrived at a figure of £1,530,000. I should like to state quite clearly what this figure is supposed to cover. It covers track equipment, including structures, copper conductors, bonds and connections to sub-stations; sub-stations, including sites, buildings, foundations, transformers, rotary converter machinery and switchgear; the electrical equipment of the rolling stock (not the rolling stock itself, which must be purchased whether steam or electric traction is used), and the high-tension transmission system. I mention this figure with every reserve, for anyone who is acquainted with engineering estimating well knows that close estimates can only be obtained when the estimator possesses a complete knowledge of the actual conditions. I give the figure merely to indicate the kind of capital expenditure needed. I wish to emphasize that I do *not* say that the Glasgow suburban railways can be electrified for £1,500,000 or so. What I do say is that the parts chargeable to electrification of the special scheme I have described above should not cost more than about £1,500.000.[ix.] Whether this special scheme could be applied to Glasgow is a matter for detailed investigation.

We now come to the annual expenses. These three electrical systems, track equipment, the sub-stations, and the high-tension transmission system, have to be looked after. I have made a rough estimate of what these annual costs would be and have arrived at the following figure, which is again given with every reserve:—

Annual cost (Electrical), £45,000 per annum.

Up till now I have only shown you ways in which electrification can spend money. I had better now try to show you some of the ways in which it can save money. The problem we have is this—we have 2,600,000 train miles to run; what will the cost of running this service be under electric, as compared with steam, traction? If the steam service is to be as good, at least as many trains must be run,

(ix.) No capital is chargeable for power plant since we propose to assume that power is purchased ready made at a figure which includes all the capital charges on power plant, as well as a reasonable profit to the supplier of power.

and the steam service must be debited with all the extra coach-mileage it must run owing to shunting difficulties and the difficulty of breaking up steam trains. Even so, it will be a dirty and noisy service as compared with a clean and quiet one, but we will not debit it with anything on this score.

Power.—I want to make the line of argument, regarding the supply of electricity, quite clear to you. We want a certain amount of electricity to drive our electric trains—some 43 million units per annum. I am going to assume that this electricity can be bought to-day at ½d. per unit, bearing in mind that the quantity mentioned is measured as high-tension electricity delivered from the power station bus bars, and is therefore inherently cheaper stuff than the direct current used by the train. This is a fair figure: it is a fair price to pay and leaves a fair margin of profit for the suppliers. This point being disposed of, we need not bother ourselves any further about the power station capital cost, the cost of repairs to power station machinery and so on. All this is included in the price debited to electric traction for the electricity used.

Now, what have we left to consider? We have to compare the actual cost of running trains by electricity and by steam. The best thing I can do to show you how these costs compare is to give you the actual average figures of the British Railways for 1922.*

There is a considerable volume of traffic now run electrically, particularly round London; indeed, in 1922 the useful electric train mileage amounted to about 10% of the useful steam train mileage, so that a definite amount of information is here available. The Railway Returns for 1922 show that the cost of actual train working—that is to say, crew's wages, fuel, water, lubricants, stores, and a few miscellaneous items—was £37,600,000 for steam, while the useful train mileage was 336·7 million. On the other hand, the electric train working expenses, including wages of motor men, electric current, lubricants, and other stores, amounted to £1,789,000, covering a useful train mileage of 32·17 million. These figures do not include guards' wages, nor the cost of cleaning carriages, nor lighting, nor—

* See overleaf.

most important of all—the cost of repairs and renewals, especially of the locomotives. However, as they stand, they show an average steam cost per train mile of 26.81d., whereas the electric cost per train mile is 13·35d. for the items covered. Now, the latter figure

***Table III.**

RELATIVE RUNNING COSTS PER TRAIN-MILE
(BRITISH RAILWAYS, 1922).

Item.	*Steam.*	*Electric.*
Wages (Excluding Guards), ...	Pence. 14·37	Pence. 2·82
Fuel (or Electricity), ...	10·56	7·43
Water, ...	0·65	—
Lubrication, ...	0·37	0·18
Stores, ...	0·57	0·32
Miscellaneous, ...	0·29	—
Repairs and Renewals (Locos. only), ...	9·55	(1·60)
	36·36	12·35

These figures are averages for Great Britain. They include all Steam and Electric Working and are based on figures given in the Railway Returns for 1922, published by the Ministry of Transport. (Electricity reckoned at ½d. per unit H.T.)

covers electricity costing on an average about ·68 of a penny per high-tension unit. This is not a high figure compared with the figures of ½d. that I have mentioned, for it must be remembered that it covers the high cost of coal in London, together with the high Municipal rates that are payable there. When this adjustment is made the figures of 13·35d. becomes 10·75d., so that the figures are :—

Average steam costs per train mile (excluding repairs and renewals), 26·81d.

Average electric costs per train mile (excluding repairs and renewals), 10·75d.

Now the repairs and renewals to the electric trains probably did not exceed 1·6d. per train mile, though this is not positively stated in the Returns. The actual amount paid for repairs and renewals to locomotives is very easily found, for, apart from superintendence, £13,390,000 was spent in 1922 on locomotive repairs and renewals, giving an average figure of 9·55d. per useful train mile.

We therefore arrive at the comparison:—

Average steam costs, including locomotive repairs and renewals per train mile, - - - -	36·36d.
Average electric costs, including repairs and renewals to equipment, per train mile, - - - -	12·35d.
Giving a balance of (about) - - - -	2/-

If I were to suggest taking the difference between these figures, namely, 2/-, per train mile, as a saving that electrification could bring about, a proper objection would be that these figures are an unfair comparison. It would be pointed out that they are the average figures for the steam service over the whole country, both goods and passenger, while the electric figures are the figures for the relatively light suburban electric trains run round London. Again, it may be said that the figures are quite irrelevant to Scottish railways, for no specific figures for Scottish Railways are given. Now, so far as this point goes, the wages paid are trade union rates for Scotland and are not, so far as I know, materially different from those paid in England. On the other hand, the Railway Returns to which I have referred show distinctly that the *coal consumption on the Scottish lines is considerably heavier than it is on the average English lines.* Indeed, it seems to be some 50% higher in places. Nevertheless, it is probable that from a variety of circumstances, the Glasgow suburban steam figure is less than 36·36d., but it is not likely to be very much less.(x.) However, I do not want to press the matter beyond a point that you will admit is distinctly favourable to the steam case, so *I propose to credit the electric working*—not with a saving of 2/- per train mile,

(x.) The Railway Companies alone possess the actual figures.

or anything like it—but *with* 15d. *per train mile only.* From the figures I have given, you will see that there is every reason to believe that, if the actual figures for the Scottish railways were examined, the savings would exceed 15d. per train mile. Any saving above 15d. per train mile is merely an increased profit in favour of electrification.

I should like to show you another lot of figures on the relative cost of steam and electric traction in Italy which have just been published.(xi.) The Italians have a good deal of electric railway in operation now.

Table IV.

COST OF ELECTRIC TRACTION COMPARED WITH STEAM IN ITALY (1921-1922)

(*From Report on Italy—Dept. Overseas Trade,* 1924).

Expenses per ton-kilometre hauled.	Steam Centesimi.	Electric Centesimi.
Locomotive staff,	0·930	0·609
Fuel,	1·920	—
Electric Energy,	—	0·259
Supply and Pumping of Water,	0·010	—
Upkeep of locomotives,	0·850	0·506
Working and Upkeep of Fixed Plant,	—	*0·486*
Total,	3·710	1·860

I do not propose to convert this Italian currency into British money, for this would be dragging in an irrevelant exchange question. It is the comparison that is interesting, and these figures are particularly interesting because they are an actual comparison under working conditions. Everything is reduced to a ton-kilometre basis. The item for " working and upkeep of fixed plant " is an item that we have

(xi.) Dept. on Overseas Trade. Report on Italy, December, 1923, by Henderson & Carpenter, 1924.

considered in this Paper separately as an annual expense of working the electrical system. To put these figures on the same basis as Table III., we must take out this figure in getting the relative "running costs" per ton-kilometre, as we are understanding the term—"running costs"—in this Paper. The comparative figures in Italy are then 3·71 centesimi for steam and 1·374 centesimi for electric—a difference of 2·336 centesimi. In fact the electrical running costs are only 37% of the steam running costs. This comparison is a rather special one because the electric power for the trains is generated hydroelectrically,(xii.) at all events to a large extent, while coal is dear in Italy. The figures themselves show that there is a difference, as regards "cost of power," between steam and electricity of 1·66 centesimi. But apart from this a *further* considerable saving is shown—amounting to about 18% of the steam "running costs"—on the other items, viz., upkeep of locomotives, water, and locomotive staff.

I would add that I have made an independent estimate of comparative costs for suburban trains *in Scotland*, on a strictly comparable basis, and find the difference in favour of electricity to be some 1/6 per train-mile—a further justification—for what it is worth—of the figure I propose to take, viz., 15d. per train-mile.

How are such savings made? Let us take coal first of all. The thermal efficiency of a steam locomotive—even the best of them—does not exceed some 5%, and this figure, even, does not include any stand-by coal. This very bad efficiency is due largely to the fact that the grate is comparatively small for the quantities of coal that have to be burned on it, so that the grate efficiency is very poor; the locomotive steam engine is also not a condensing engine, the steam being discharged straight to the atmosphere through the locomotive up-take. In the power station about two-thirds of the energy taken out of 1lb. of steam is taken out of it below atmospheric pressure. This

(xii.) It must not be assumed without further question that hydroelectric power is less costly than steam-generated electricity. Modern steam plants are highly efficient while there are civil engineering charges on hydroelectric schemes that may or may not be heavy.

figure is comparable with 12% which is the over-all efficiency *now* obtainable with electric traction in systems of the size we are discussing to-night.(xiii.) In mentioning 12%, I have made full allowance for all electrical losses in getting the electricity to the trains, including the losses which arise in the train motors themselves in using electric power for haulage. The comparison is therefore a true one between mechanical draw-bar power and heat in coal used. It is obvious then that there must be a decided saving in coal. But the story is not yet told. There are even heavier savings in the labour costs, though there are not necessarily savings in wages. The wages paid to the men are not necessarily less than the wages paid to locomotive drivers—it is no part of an electric scheme such as this that they should be. The reasons for the saving in labour charges is not that you pay the men less—but that the men waste less time. They do not have to spend hours a day, as the steam locomotive men do, in running-sheds, "making-ready" their engines for the duties they have to perform, and in conducting complicated shunting operations. All the motor man has to do is to get his handle and he is ready to begin. Then the stoker is not there. The running-shed expenses are necessarily much less. Very heavy savings are made, as our figures show, in repairs and renewals to the locomotives as compared with the electrical equipments. The locomotive boiler—a very costly item to repair—is again simply not there. There are other items upon which decided savings could be made by electric working, namely, the cleaning, lubricating, and lighting of vehicles, and shunting expenses, but we do not propose to take these into account as it is unnecessary for our purpose this evening, which is merely to show that, prima facie, a substantial financial case exists for electrification.

How does the comparison work out on a basis of 15d. per train mile? Here is the conclusion of the whole matter:—

(xiii.) In reading this statement in connection with the relative costs of fuel and electricity shown in Table III., it must be remembered that the cost of electricity shown there includes many other items as well as coal.

SUMMARY OF FINANCIAL RESULTS.

(1,500 Volt Direct Current Scheme).

Item.	*Per Annum.*
Saving in Running Expenses on Steam Operation, ...	£164,000
Cost of Operating Electrical System, ...	£45,000
Net Saving (Difference), ...	£119,000
Capital Charges at 7% per annum, ...	£107,300
Balance, ...	£11,700

This table shows that, allowing for capital charges of 7%—that is 5% interest, with 2% for depreciation, etc.—there is a balance left over of about £12,000 per annum.

On the basis of this rough examination, I submit that there is, prima facie, a distinct financial case for the electrification of the Glasgow Railway system within, say, 10 miles of the city, for I have been deliberately conservative in these estimates, and have left out many items for which credit should be taken, such as increased revenue from the improved service,[xiv.] reduced expenses of carriage cleaning, use of existing cable networks, and so on.

Judging from other railway electrifications with which I am familiar, I am confident that these credits would far more than off-set the additional capital charges arising from capital that would have to be spent on alterations to ways and works, car-sheds, signalling

(xiv.) *Monetary Benefits of Electrification.*—The following paragraphs are abstracted from the Annual Report of the Victorian Railway Commissioners for the year ending 30th June, 1923:—

(a) Since electric traction was commenced in May, 1919, there has been a large development in the suburban passenger business, the total number of suburban passenger journeys having increased from 104,000,000 in the year ended June 30th, 1919, to 146,000,000 at the close of the financial year 1922/23, representing an advance of 40%.

(b) During the ten years preceding the introduction of electric running the annual rate of increase in the suburban passenger traffic averaged approximately 4%, and after allowing for such increase, the additional traffic brought to the Railways by electrification is equal to not less than 20,000,000 passenger journeys per annum.

alterations, etc.[xv.] Proper capital credits must, of course, be allowed for the locomotives freed for duties elsewhere, since there is no need to scrap these.

Housing and Transport—One Inseparable Problem.—If the people are to live over a larger area, they must have houses in suburban districts and means of transport to get to and from their work in the city. It is of little use considering the housing question as one self-contained problem and the transport question as another. The two questions are simply two different aspects of the same problem—how best to spread the population over a larger area. It will be a disaster if the new houses in Glasgow are to be barrack-like structures built on the immediate outskirts of the city and served by trams. Such houses will simply be part of the slums of 1975. Here we come to the crux of the matter from the administrative point of view. At present the housing scheme is being considered by the Corporation with the Ministry of Health; the Corporation control a Tramway System; the Railways are controlled by private companies; motor-bus rights are, so far as I know, still in abeyance; property in the surrounding suburbs is largely owned privately. No single body, at present organised—even with the best intentions in the world—has power to investigate the housing and transport problem of Glasgow as a single problem. The Corporation proposes, I understand, to clean out St. Enoch's Square to make a car park for a system of transport that is obsolete. Then there are other proposals for building bridges. All these moves are merely moves to decrease temporarily the congestion that is brought about through the con-

(xv.) It must be borne in mind throughout that rolling stock must be provided with either system. The amount required is settled by the requirements of the peak traffic, the speed of the service, and the amount out of commission for repairs. Inasmuch as the train equipments form an integral part of the rolling stock (the motor coaches), whereas a steam locomotive does not, the amount of *rolling stock* to be set apart as out of commission for repairs will be somewhat greater with electric traction, but, on the other hand, an improved schedule speed would usually be given which would offset this. The net result is that the amount of rolling stock, qua rolling stock, required upon either system of traction would be very much the same for a given peak traffic. Consequently we can leave this item of cost out of our accounts altogether in a comparison between the two systems, for it is a definite expense that must be incurred upon either system.

tinued use of a system of transport that is out of date. They do not touch the root-trouble. I suggest to this meeting that what Glasgow wants is a Royal Commission, appointed by Government, to investigate the housing and transport question as one problem. The reason for bringing the Government in is that no other body has the necessary power. I respectfully suggest that such a Commission should be formed of Glasgow men who are thoroughly familiar with the local conditions. There is precedent for this suggestion. A Royal Commission was appointed to investigate London Traffic, and published a most useful Report in 1905. The London Traffic Branch of the Board of Trade also reported in succeeding years, up till 1912 at all events. I suggest that the Glasgow Commission should have fuller powers than the London Traffic Commission. It should have powers not merely to investigate the traffic problem, but the housing problem as well (at all events, as regards the localities for houses), so that a really well-thought-out and consistent scheme of development can be planned for Glasgow.

Big schemes for electrification are in hand in the United States of America, and on the continent of Europe. In France, for instance, plans are completed which cover about one-third of the French railway mileage, while electrification in Italy is being speeded up. These schemes are certainly not going forward without real justification. The authorities carrying them out are electrifying their railways to make them more effective agencies for transport.[xvi.]

We are on the eve of developments in railway electrification in this country. Is Glasgow to share in them or to be left out in the cold?

Conclusion.—These are the conclusions I have reached:—

(1) I believe that a detailed investigation would show that it would be financially sound to electrify the suburban railways, as regards passenger traffic at any rate, within, say, 10 miles of the city. At all events, there is a prima facie case for electrication.

(xvi.) See interesting articles in the *Manchester Guardian Commercial Annual* (1925), pp. 40 and 44.

(2) Such a service would benefit Glasgow in many ways:—

(*a*) It would enable the population to be spread over a much larger area.

(*b*) It would do something to abate the smoke nuisance in the City.

(*c*) It would do away, to a large extent, with the filthy tunnels that we have.

(*d*) It would enable the housing scheme to be linked up with a suitable system of transport.

(*e*) Last, but by no means least, it would provide useful work for some of Glasgow's unemployed. In talking of the unemployed, one often is tempted to think of the unskilled man only. It is not the unskilled man only who is in difficulties in Glasgow. Engineers and riveters are in very sore straits. Now the expenditure of $1\frac{1}{2}$ to 2 millions of money, say, on electrification, would provide a good deal of work locally. There are probably no items that could not be manufactured in this district.

These are the reasons why railway electrification has very decidedly something to offer Glasgow. The time is now ripe for Parliament to set up a Commission, with full powers, to study, as a single problem, the housing question and the transport question of the City of Glasgow.

By Professor S. PARKER SMITH, D.Sc.

(*Read before the Society, 28th January,* 1925).

[Abstract.]

In 1895—30 years ago—a lecture was given before this Society by Mr. W. B. Sayers, on the "Domestic Applications of Electricity." Developments have been slow, despite the great advantages offered by electricity in regard to health, cleanliness, air purification, etc. A great impetus of recent years has been given to the wider adoption of electrical appliances in the home by the increasing difficulty in obtaining domestic servants. Experience is proving electricity to be a good servant. Moreover, supply authorities are now looking with great favour on the domestic consumer who uses electric energy for other purposes than lighting. Instead of selling a few units at a high rate, the supply engineer now prefers to sell a much larger quantity at a price which makes electricity an active competitor with other forms of energy. In the opinion of engineers in some municipal areas, it is possible that in the near future the domestic load may equal half the load on the station.

The lecture was illustrated by a description of a 10-roomed house (3 reception rooms, 5 bedrooms, kitchen, and nursery), built by the lecturer within the Glasgow Corporation Electricity supply area with the intention of using electricity throughout. Neither coal nor gas is used.

Wiring.—The cab-tyre sheath (C.T.S.) system of wiring is used throughout. Apart from questions of cost and relative merits, screwed tubing would have been impracticable in many places, owing to the large numbers of wires. A large number of switchplugs—about 36 in all, is used. These are fixed in the skirting board and foot-operated. There is a separate circuit for each switchplug. At the distribution board there are four meters for registering the energy used for lighting, cooking, hot water and heating; also a two-rate

meter for registering the energy used during day time and during night time. This two-rate meter is controlled by a clock which switches over at 11 p.m. and at 7 a.m. Normally, only the two-rate meter would be installed, as the other four meters are merely for separate measurements.

Bells.—To prevent the common trouble due to wiring faults, C.T.S. wire was also used for these circuits. There are three bells—a deep-toned bell for the front door, a shrill-toned bell for the side-door, and a gong for the house service.

Lighting.—Lighting forms such a small percentage of the total cost that there is no great need for economy in this direction. The cost of lamps is more important than the cost of energy. Abundant lighting is provided throughout. Exposed filaments are avoided. Wherever desirable, two-way and intermediate switches are used to enable lights to be operated from any desired point. Thus the hall light is controlled from four points, while the lights for stairs and landings are operated from seven points. The dressing table lights in bedrooms are controlled from both door and bed, while a separate bedlight is also provided.

Cooking.—There is a service from kitchen to dining-room, via pantry. In the service cupboard in dining-room there is a warming plate for warming plates or dishes and for keeping food hot. The cooker is of the table type, i.e., the oven is alongside the boiling plates, so that stooping is avoided. The cooker is placed in the kitchen—no scullery being required, as there is neither smoke, smell, nor dirt. The oven is provided with a thermometer and rustless steel shelves. Both oven and griller have proved eminently satisfactory. Hot plates are apt to be slow and in the open type the elements are apt to burn out if milk boils over—a safe and quick boiler for fatty liquids will be a great improvement, and work is being done in this direction.

Washing.—A drying closet in the kitchen is provided by means of an exhaust fan, clean air is drawn through a grating in the floor and heated as it passes over an air warmer. One hour suffices for drying.. The clothes are washed in a boiler of the " Blighty " pattern, placed in the kitchen—this washer acts as a percolator, and no

scrubbing of clothes is needed. This arrangement makes drying independent of the weather and renders a scullery superfluous.

Heating.—Heating by means of radiation is the mode adopted, except in the hall, where a small convector (air warmer) is installed. Radiant heat is regarded as the most desirable form of heating, because the air can be kept cool and fresh, while the occupants in the room can enjoy the same kind of heat as is obtained from the sun. It is the radiant heat from coal and gas fires which is most valuable for room heating. In the living rooms an electric fire of an attractive type is placed in a recess, as in an ordinary fire place, but in addition a small bowlfire is placed in another part of the room so as to obtain the heat where it is required. If necessary, more than one additional fire is used ample switchplugs being provided. It is found to be better to distribute the heat in this way, both as regards economy and comfort. In the bedrooms, etc., small portable fires are used—these can be placed where they are needed.

Special mention might be made of refuse disposal, as this seems to be a matter of much importance to some people. With a self-contained house the question need not arise, as the refuse can be put into a closed bin outside the house. Occupants of all-electric flats can overcome any difficulty by taking the refuse to the outside bins at frequent intervals and not allowing it to pollute receptacles in the kitchen. In any case, burning garbage on a sitting-room coal fire is an objectionable practice.

Ventilation.—Special attention was given to this. An inlet is provided at the back of each fire recess, the top of the recess being closed by a plate. In the frieze a grid outlet is provided to allow vitiated air to escape into the flues of external chimney breasts. In this way the heated and polluted air is carried off.

Hot Water.—In order to obtain an abundant supply of hot water economically, a low tariff is essential. By utilising electricity during night-time only for this purpose, the Electricity Department propose to charge 0·375 pence per unit. The heated water is stored in a 90-gallon, well-lagged tank. In this way an ample supply of hot water

in the bath-room, kitchen, pantry and cloak room is obtained. The tank is placed in the bathroom, so that any loss from it is useful in warming this room.

Auxiliary Apparatus.—All appliances such as kettle, coffee percolator, flat iron, vacuum cleaner, toaster, etc., are fitted with plugs so that they can be used in any socket in the house.

Consumption and Costs.—In order to appreciate clearly the figures for electrical energy, it is needful to have corresponding figures for other forms of obtaining heat, etc., in other words, comparative figures are essential for a proper understanding. For the six months: July, 1924, to January, 1925, the total cost of electrical energy was £22, which worked out at an average of 16/11 per week—2/5 per day and 5d. per day per person. This cost was based on $\frac{3}{4}$d. per unit for the day load (the minimum to which the charge was allowed to fall for ordinary domestic use), and $\frac{3}{8}$d. per unit for the night load (hot water storage), a special tariff which it is intended to apply to such loads.

An analysis of the figures showed that of the units used, 34% was used for heating, 45% for hot water, 17·5% for cooking, and 3·5% for lighting. From these percentages it will be seen that nearly half the load—for hot water—is taken at night time and remains constant throughout the year. Further, cooking is constant, though a day load. Thus, altogether, about two-thirds of the load on the station is constant. It is this fact which enables supply authorities to sell energy so cheaply for domestic purposes. As regards lighting, the cost is seen to be negligible.

Security.—The reliability of the service has been all that could be desired. The electric supply has not once failed, while the several appliances work very satisfactorily.

Advantages.—There is no need to do more than mention the merits of electricity as regards health, cleanliness, economy in labour, convenience, comfort, etc., in the home, and the benefit which the community derives from all householders who avoid polluting the atmosphere with smoke.

Soda, Nicolas Leblanc, and the French Revolution.

By Professor T. S. PATTERSON, Ph.D., D.Sc.

(*Read before the Society, 5th November,* 1924).

In the north of Africa, south of Tripoli, there occurs native, a double salt of sodium carbonate and sodium bicarbonate, of formula $Na_2CO_3.2NaHCO_3.2H_2O$. This substance was presumably known to the Egyptians and, through them, to the Israelites whose name for it was "nether"—which was either the Egyptian word itself, or was derived from it. This word passed into Greek as "nitron" and into Latin as "nitrum," connoting the same substance. It also passed, apparently through the Greek, into Arabic as "natrum" or "natron," which became shortened to "tron"; and "trona," derived from this, is quite a modern European name for the compound. The substance was imported, until comparatively recent times, for washing purposes and for making glass.

It was doubtless also known at a very early date that the ash obtained by burning sea-weed had very similar properties. When the Arabians settled in Spain about 700 A.D., they either introduced, or they encouraged the cultivation of, a sea-shore plant, whose name was probably "kali," which in turn may have been derived from a Hebrew root meaning to burn. The ash of this plant is particularly rich in soda, and to the ash the name "kali" or "alkali"* was transferred, presumably by the Arabians who took up the study of alchemy, possibly deriving it from the Egyptians. It was vigorously prosecuted by Geber who is thought to have flourished at Seville about 760 A.D.

* In modern times this was ousted by a native Spanish name for the plant—which was then transferred to the ash—"bariglia" in the XVII. century and "barilla" at the end of the XVIII., and in the XIX. century.

At any rate the word "alkali" occurs first in the (Latin translations of the) writings of Geber, where also the word soda is used for the first time in exactly the same sense.*

It was known, also at an early date, that the ashes of land plants yielded a substance similar to that from sea plants. But to the Egyptians with their supply of trona and to the Arabians in Spain, with considerable quantities of sea-weed ash and the ash of the plant kali, the ash containing sodium carbonate was probably commoner than the ash containing potassium carbonate. The Arabians may also have added, to the methods of producing alkali, the charring of argol or tartar, the potassium hydrogen tartrate which separates on the sides of the casks when grape juice is fermented. (Kopp, iv., p.5). The words natrum, kali and soda were all applied to any of these products, and at the most, might be used to differentiate between sources, or methods of preparation.

Then in the 13th century the name sal nitri came to be used for potassium nitrate, in place of sal petrosum (Kopp, iii., p. 221), and this was shortened into nitrum and ultimately became nitre, in English; but the words "kali" and "natron" continued to be used indiscriminately for potassium carbonate or sodium carbonate. This new use of the words "nitrum" and "nitre" led to some confusion as is indicated by two passages of the authorised version of the Bible,† in which the translators did not distinguish the Hebrew "neter," and its equivalent nitrum and nitron, of Latin and Greek, from the comparatively modern word "nitre." Attention was first directed to this by Robert Boyle in 1680,‡ who took some trouble to obtain Egyptian nitre and compare it with ordinary saltpetre.

The development of the chemical idea of salts led to the suggestion of a basis for a common salt, and by the investigations of Stahl in 1702,

* Kopp: Geschichte der Chemie, iv., p. 35.
It is very remarkable that nothing appears to be known of the origin of the word soda, one of the commonest in modern chemistry. Avicenna (980-1037) treats of soda, which he says is the juice of a plant "sosa" (Thomson: History of Chemistry, I., 138) but whether he uses the name "soda" or not I do not know.

† Prov., xxv., 20; Jer. ii., 22.

‡ Experiments and Notes about the Producibleness of Chymical Principles, p. 30; Works, 1725 Ed. III., 371; 1744, Ed. I., 381.

Duhamel in 1736, and Margraaf in 1759, it was recognised that this basis—what we call base—was the same as the alkali derived from trona and from the ashes of sea plants, but different from that obtained from land plants and argol. This brought about the separation of the alkalis into vegetable and mineral, Guyton de Morveau* afterwards introducing the terms, potash and soda, for the caustic alkalis. Of the mild alkalis, the vegetable one, potassium carbonate, was the cheaper.

But, since civilisation was progressing, and since what we call civilisation depends largely upon soap, both alkalis were becoming necessary in a continually increasing quantity, whilst the supply, especially of soda, did not keep pace with the demand.† Naturally, therefore, whenever it was discovered that sea salt and soda were derived from a common basis, many attempts were made to prepare the latter valuable product from the former cheap one.

This was the condition of affairs when at Yvoy-le-Pré, in the year 1742, Nicolas Leblanc made his appearanace in this rather casual world.‡ Little is known of his youth. His father, who was the manager of a forge at Yvoy, died in 1751, from which time until 1759 he was under the protection of a M. Bien, an eminent surgeon of Bourges, who died in that year. This connection probably decided Leblanc's choice of a profession; about 1760 he became a pupil at the school of Surgery under Brasdor at Paris. There Lavoisier, Vauquelin, Haüy, Fourcroy and others were his contemporaries, in fact nearly all of that school of young French chemists, who, following the lead of Lavoisier, and seizing on the facts accumulated by the somewhat embarrassed Phlogistians, succeeded in changing the old order and in establishing what they proudly called—although not much to the liking of Lavoisier§—" La Chimie Française."

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* Jour. de physique, 1782, *19*, 379.

† So that soda was sometimes even prepared from potash by the action of sodium sulphate, and then crystallisation (Hagen: Kopp, IV., 38).

‡ I am indebted for many details of Leblanc's life to the book by Anastasi (Leblanc's Grandson): " Nicolas Leblanc " (Hachette, Paris, 1884).

§ Oeuvres de Lavoisier: II., 104. "Cette théorie n'est donc pas, comme je l'entends dire, la théorie des chemistes français, elle est *la mienne*, et c'est une propriété que je réclame auprès de mes contemporains et de la postérité."

Leblanc, after becoming a master in surgery, practised in Paris, and in 1780 became surgeon to the Duc de Chartres who in 1784 became Duke of Orleans. Here Leblanc was the colleague of Berthollet*, who was physician to the Duke, until he also gave up the practice of medicine and devoted himself entirely to chemistry.

This Duc de Chartres must have been of great importance to Leblanc and Berthollet; and Leblanc and Berthollet, as his surgeon and physician respectively, were probably of great importance to him; and although Carlyle's portrait of the Duc is hardly flattering, let us credit him with his assistance of Leblanc. Amongst other idiosyncracies, he dabbled in chemistry, and in his establishment Leblanc was able to work congenially.

It has already been remarked that the necessity for sodium carbonate was becoming ever more pressing, and various processes for its production on the large scale had been attempted. Scheele, in 1775, had proposed the action of sodium chloride solution on lead oxide, $2NaCl+PbO+H_2O=2NaOH+PbCl_2$, which in itself indicates the value of soda at the time if lead oxide could be used for its preparation. An attempt to work this process on a manufacturing scale was made by Kirwan in England in 1782. (Kopp, iv., 38).

Another process was suggested by Scheele in 1779, depending upon the action of iron, or iron and lime, on sodium chloride solution. $12NaCl + 4Fe + 3O_2 + 6H_2O = 12NaOH + 4FeCl_3$. This was tried by Guyton de Morveau in 1783 (Kopp, iv., 38, 39) and was still in operation in 1794.

In 1658, Glauber, in his "De Natura Salinum," had described the "Sal mirabili Glauberi," the residual product in the preparation of hydrochloric acid, a salt which was regarded as miraculous, partly because it had medicinal properties, and partly because it was supposed to dissolve carbon, since, when strongly heated with carbon, the product (sodium sulphide) was soluble in water. In 1777, Père Malherbe suggested the action on sodium sulphate of a mixture of

* T. Thomson: History of Chemistry, II., p. 141, says Berthollet was physician to the *father* of Egalité.

carbon and iron which yielded a product containing sulphur, sodium and iron, which deliquesces in air, taking up carbon dioxide and yielding some soda. About 1777* De la Métherie (Journ. de physique, 1789, *34*, 44) had proposed to calcine sodium sulphate with carbon, supposing that sulphuric acid would be decomposed to yield sulphurous acid and leave pure soda behind. He also proposed that part of the product, a hepar of sulphur (sodium sulphide), might be treated with acetic acid or other vegetable acid to give acetate of soda which on calcination would yield soda.

But these were not satisfactory processes, and, about 1782, the economic production of soda had become so important that the Academy offered a prize of 12,000 (24,000 Kopp) livres for a good process. None of those then available was adjudged to be of sufficient merit.

It may possibly have been the offer of this prize, or it may have been merely general scientific interest which attracted the attention of Leblanc; indeed the problem was one likely to fascinate any chemist, capable of appreciating the enormous possibilities of such a manufacture. The raw material very cheap (except for the Gabelle—salt tax—see p. 129) and easily obtained; the finished product, expensive, absolutely essential and used in great and continually increasing quantities—in consequence of which the price was steadily rising. France, it has been estimated, paid to foreign countries—chiefly to Spain for barilla—no less than 30,000,000 fr., which, considering the value of money at that period, was a very considerable sum.

Leblanc commenced his experiments in this direction in 1784, but we hear nothing of them for some time. Simultaneously with them he was busy with others. In 1787 he published a research on the crystallisation of neutral salts† (Journ. de phys., 1787, *31*, 29), see also J. de phys., 1788, *33*, 374); and another on cubic alum and

* Anastasi, 171.

† Shortly before the end of his life, when his affairs were at a very low ebb, he published another paper on crystallisation, a subject which apparently had special attractions for him. Jour. de phys., 1802, *55*, 300.

cobalt vitriol (ibid. *31*, 241); in 1788, one on spontaneous combustion of oil; and, in consequence of a great fire which had broken out spontaneously, he also carried out comparative analyses of French and English coal. He gave, then, at this time distinct evidence of becoming an important scientific worker, and the successful result of his experiments on the production of soda was apparently not due to a fortunate chance, but to carefully conducted and intelligent research.

Leblanc, recognising that the processes already in existence were either incomplete or too expensive, succeeded in overcoming all the difficulties and rendering the process one of very considerable simplicity by merely fusing the sodium sulphate and carbon with the addition of calcium carbonate, much the cheapest and best method of supplying the requisite carbon dioxide.*

The year 1789, which saw the completion of his labours, also ushered in the Revolution; and the extraordinary events of the year or two preceding and of those following, must have had a special interest for Leblanc on account of the part played by his patron. In the meantime things probably went well enough, for Orleans was antagonistic to the King and was trying to ingratiate himself with the people.

Leblanc suggested to the Duke of Orleans in 1789, the operation of his process on the large scale. Orleans requested the advice of d'Arcet, Professor of the Collège de France, and tests were carried out by one, Dizé, who was préparateur there, and who thus came into contact with Leblanc. D'Arcet's report was very favourable (Anatasi, 17) and on the 12th of February, 1790, an agreement was signed before John Lutherland, a public notary, in London, between the Duke of Orleans, Leblanc, Dizé, and Henri Shée, the last being Orleans' agent. This agreement was in respect of the loan by Orleans of 200,000 livres (tournois) to work Leblanc's process as well as a secret process by Dizé for making white lead, and one for making sal ammoniac, a

* He regarded it himself as the completion of the process of de la Métherie of 1789 (De la Métherie, Jour. de Physique, 1789, *34*, 44; 1809, *69*, 442; Anastasi, 175. In the second reference a quotation from a Mémoire of 1798 by Leblanc is given.

description of the processes being deposited on 27th March, 1790, with a notary at Paris, accompanied by a certificate from d'Arcet (dated 24th March, 1790) stating it to be the process which had already been tested by him. (Anastasi, p. 180). It seems strange that this agreement should have been signed in London, but this was probably because the Duke of Orleans—who aimed at the throne; who was hated by Marie Antoinette; who had deliberately encouraged the revolutionary element, and had joined the National Assembly (Tiers Etat), June 25th, 1789—had found it convenient to leave France;* and seek change of air in London (October, 1789—July, 1790), where in any case he had often visited. He was an intimate friend of the Prince Regent—afterwards George IV.—a friendship not calculated much to improve the morals of either high contracting party.

At this time the Gabelle was in existence, and, of course, must have had a serious effect upon an industry depending upon sodium chloride. The tax varied in different parts of France, but Paris was situated in the Pays de Grande Gabelle, where everyone over eight years of age was assumed to use nine pounds per head per annum, the duty on this being assessed at 62 fr. per quintal. This tax was reduced on September 23rd, 1789, and abolished on March 26th, 1790,† which, naturally, much simplified the problem of the manufacture of soda.

Then on 27th January, 1791, an association was formed between Nicolas Leblanc (soda), Michael Jean Jerome Dizé (white lead), and Henri Shée (representing Orleans), and a factory was established at St. Denis. Orleans was to get 10 per cent. interest on his money, and Leblanc, at least 4,000 livres per annum; Dizé, 2,000 livres, if the profits should not otherwise reach these amounts.‡

Meanwhile the Constituent Assembly, in 1791, passed a patent law guaranteeing to inventors a fifteen years' monopoly. Leblanc at once took advantage of this, and the fourteenth patent under the

* Cambridge Modern History, 1904, VIII., 185.
† Loc cit., pp. 696, 697.
‡ Anastasi, p. 184.

new law was accorded to his process.* The works were now in full activity and were turning out five to six hundredweight of soda a day.

About this time the prevalent political excitement was beginning to infect scientific bodies, and Lavoisier—who had been drawn into politics at an earlier date, and who was perhaps the most prominent scientist in France at the time—became, as a landowner, the object of an altogether unmerited suspicion. It was not long until the Convention began to suspect the Academy—of which Lavoisier had become Treasurer in 1791 †—of "incivism." Fourcroy, who had been associated with Lavoisier in earlier years, moved in Spring, 1792, that members suspected of "incivism" should be expelled, and although the proposal was rejected for the moment, it was clear that danger threatened. On August 10th, 1792, Vernigaud, in the Legislative Assembly, and at the Dictation of the Commune, proposed the summoning of a National Convention, and on September 5th Robespierre, Danton, Marat, Camille Desmoulins, David ‡ and others were elected for Paris, along with Orleans—who owed his election to Jean Paul Marat §—as the last member. On the 15th September of the same year (1792), by permission of the Commune, Orleans changed his name to Philippe Egalité.

At this time, shortly after the establishment of Leblanc's factory, France, in addition to her internal troubles, was becoming involved in difficulties with other powers. The terrible September 2nd massacres, the establishment of the Republic "one and indivisible" (1792), the success of the French arms at Valmy (September 20th) and Jemappes (November 6th), produced a general confusion and frenzy, which was no way allayed by the trial of Louis XVI. in the last days of December, 1792, and the first days of January, 1793. By the vote he then gave Orleans became a regicide and Louis died on 31st January, 1793. This naturally increased the prevailing confusion

* Anastasi, pp. 19, 185.

† Grimaux: Lavoisier, 1888, p. 148.

‡ The painter of the well-known picture of Lavoisier and Mme. Lavoisier.

§ A physician (M.D., St. Andrews, June 30, 1775). The Encyl. Britt. (9th Edn.) gives Marat a fairly good character. Grimaux (loc. cit., p. 206, 207) does not.

which was added to by the declaration of war against Britain (February 1st), against Spain (March 9th) and the declaration by the Empire against France on March 22nd.

These were exciting times in which to work out a new industry, and to Leblanc they must have been particularly so. The popularity of his patron soon began to wane; but, on the other hand, since France was now at war with almost the whole of Europe, she had cut herself off completely from the main sources of soda, especially from Spain, although possibly a little may have been produced from sea-weed along the coast. This might not have mattered so much, had it not been that the supply of potash also was insufficient, and was all used up immediately in the preparation of nitre for gunpowder. Strenuous efforts were made to utilise the resources of the nation. Chaptal was brought to Paris to act as director of the powder factories. All the leading scientists were occupied with state matters. It was a condition of affairs which we, casting our memories back a few years, are not unable to understand. So far, the success of the manufacture of soda had been considerable, but as the result of the economic conditions, prices all round began to rise, and that of soda, on account of its increasing scarcity, rose from 40 fr. per quintal (100 lbs. or 50 kg.) to 75 fr. and then to 110 fr. To stop this natural result of the general conditions, a law was passed (3rd May, 1793) which decreed a fixed maximum price for all commodities, a measure—as again we have had reason to know—tending naturally to still further chaos.

This of course rendered the management of the three-year-old factory much more difficult, and reduced Leblanc to financial embarrassments, which may seem strange as the manufactory had apparently been paying well; the profits had perhaps been largely devoted to extending and improving the works. At any rate, in 1793, his two daughters opened a small milliner's shop in the Rue St. Antoine, before the door of which the tumbrils soon rolled gaily, daily; for, about this time, Robespierre was getting well into his stride. On April 6th, 1793, the Duke of Orleans was arrested and thrown into prison.

Shortly afterwards, on the 13th July, 1793, Marat, who in his paper "L'Ami du Peuple" had been pouring out denunciation on Lavoisier, was picturesquely assassinated by Charlotte Corday d'Armans, who, in anticipation as it were, avenged Lavoisier and many others, but paid, four days later, her own expiatory visit to the Place de la Révolution. Thus, as Carlyle remarked, "the beautifullest and the squalidest come in collision and extinguish one another." But although Marat was dead his work went on and what he had desired was accomplished. On the 8th August, 1793, the Convention decreed the suppression of all the learned societies of France.

This had its effect upon Leblanc, for he either was or might have been—I have been unable to discover for certain—a candidate for the prize of 12,000 livres, which the Academy had proposed in 1782.† His process was now in full working order. He had fulfilled all the necessary conditions. The prize could hardly have been adjudicated otherwise than to him, but the Academy no longer existed to award it.

With the advent of the Terror in October, 1793, the Dance of Death became wilder than ever. On the 16th October, Marie Antoinette was executed. On the 29th Orleans was tried and condemned, and on 6th November he was executed. It was known, of course, that Orleans had been interested in the factory at St. Denis, and since the Republic had proclaimed itself heir to all the property of condemned or executed prisoners, Leblanc's factory was instantly sequestrated and work there was interrupted, which naturally caused the stoppage of other industries which were dependent upon soda. As there was no other factory capable of anything like the same production, this was a disaster of the first magnitude.

And still the work of Marat was carried on by Fourcroy, who, apparently out of fear, seems to have directed his energies against Lavoisier, and it is said to have stigmatised him as a counter-revolutionist.* Therefore, in November, the Convention ordered the arrest of Lavoisier, and, with other Fermiers Généraux, he was placed

† See Grimaux, Ch. VII. and Thomson's History, II., pp. 169-170. T. E. Thorpe: Essays in Historical Chemistry, 1902, pp. 140-147.

in the prison of Porte-Libre. This again, had a direct influence on Leblanc for on 7th January, possibly on the recommendation of Chaptal, he was appointed "régisseur des poudres et salpêtres à l'Arsenal," in succession to Lavoisier. The pressing necessity for soda soon made itself felt, and the Committee of Public Safety issued an appeal to all patriots, to place at the disposal of the Nation, any secrets or inventions likely to prove advantageous to it. Not to have replied to such an appeal would have been dangerous indeed. Shée was apparently the first to realise this. In February, 1794, he wrote from St. Denis, where he was in charge of the factory, to Leblanc, who, on account of his office, had to live in Paris—at the Arsenal: "Your patriotism will suggest to you at once I am sure the sacrifice of your secret, the fruit of your long and laborious researches ..... Nevertheless, thinking that your sense of honour might occasion you some scruples in regard to the enterprise, I hasten to assure you for my part—from my heart—that I consent and even invite you if it be necessary, to reveal to the nation all that you know of this important subject .... I am persuaded that Citizen Dizé will find in his patriotism all the motive necessary to approve this step." Leblanc gave up his secret and his process was published* in pamphlet form, together with a few more by Malherbe, Chaptal, Guyton de Morveau, and others. It was described fully, with plans and complete practical details, together with a report upon them all, which highly praised that of Leblanc, and added that "Citizens Leblanc, Dizé, and Shée, co-associates, are the first to present their memoirs and have shown a noble devotion to the public welfare .... The process of Citizen Leblanc by the use of chalk, appears to us that which might be generally adopted."

At the same time the factory was seized—and sold ! and Leblanc, the man of all men best able to carry on the work, was expelled (February, 1794). He probably expected that he would at least be continued in the management of the industry he had created.†

* See *Leblanc*: Observations sur la confection et l'usage de la soude. Ann. Chim. Phys., 1804, *50*, 96.

† Anastasi, p. 27.

On April 5th, 1794, Camille Desmoulins and Danton died in company, and very soon afterwards the stage was set for the tragedy of Lavoisier. In spite of much influence which was put forth on his behalf, the Terrorists under Robespierre, had their way, and on 2nd May, 1794, Dupin, in the Convention made charges against all the ex-Fermiers-Généraux, who were accordingly brought to trial on 6th May. 1794. Here, Fouquier-Tinville was the prosecutor; and Jean Baptiste Coffinhal, the president, is said to have rejected contemptiously the memorial on behalf of Lavoisier—who had asked for a respite of fourteen days in order to finish the research he was engaged on—with the words "La République n'a pas besoin de savans ni de chymistes; il faut que la Justice suive son cours." But there is some doubt about both Lavoisier's request and Coffinhal's words.* There was such a hurry to do away with them that the jury's decision was omitted from the minute of judgment—these were not times for worrying about trifles; on the 8th they were all executed. Very possibly Madame Defarge was there with her knitting and, if so, she counted "four" as Lavoisier's head fell, unless indeed, Miss Pross had squared accounts with her before this period. Head number three belonged to M. Paulze, Lavoisier's father-in-law. Poor Mme. Lavoisier! It afterwards became part of Leblanc's duties to make an inventory of Lavoisier's effects.†

By the end of June the Terror was at its most terrible, but poetic justice saw that her opportunity had come at last, and Robespierre followed his victims to the guillotine on the 27th July, 1794. With his death, the worst was over. It remained, however, to do a little clearing up. Coffinhal was arrested and executed on the 5th August, 1794, and less than a year later, on the 7th May, 1795, Fouquier-Tinville suffered the fate which he so richly deserved.

Whilst the Revolution was at its height and the law of the maximum in force, it was no wonder that industries of all sorts had

* Grimaux, p. 376.

† It is interesting to observe that of the scientists of the time, Berthollet seems to have been the only one regarded as so necessary to the country that he could dare to be independent. See Thomson's "History of Chemistry," II., pp. 144-145.

ceased to flourish, the mineral industry particularly being at a standstill. But when the Terror had passed and some sort of desire for regularity and order reasserted itself, the question of the industries was one of the first to attract notice. Leblanc was sent (June, 1795) by the Committee of Public Safety to examine and try to revivify the alum mines at Tarn and Aveyron, and there he spent thirteen weary months at his own expense.

On his return he was offered in December, 1796, a Professorship of Natural History at Alby, which he declined. In spite, however, of his pecuniary embarrassments and other worries, he contrived to carry on some scientific work, and presented a paper on nickel to the Lycée des Arts in 1798.*

He enters now upon the last phase of his career which consisted, as not infrequently happens in such cases—little Miss Flitte for example—of a constant presentation of petitions to the authorities for recognition of his rights; petitions which seem never to be successful. When the world has wronged an individual, it appears to be a law of nature that the proper reward for him is to heap indignity upon wrong and neglect on both; to stamp him out; to get rid of him. He applied for the restitution of his works and Neufchateau promised 3,000 fr. as recompense, of which, however, he only received 600 fr. Prompted by Fourcroy, who now seems to have stood his friend, he made other applications for payment of the remainder. These were answered by Quinette, Chaptal and Berthollet in succession, always with the same excuses. The Republic acknowledged its indebtedness to Leblanc, but on account of the war there was no money to pay. Resuming his petitions, he cited his services to the State, and at last in April, 1801, a decree of the Minister of Finance ordered the restitution of his works; Shée (who had become Consellor of State), and Dizé (now physlcian-in-chief to the military hospitals), both declined to have anything further to do with the factory. Leblanc therefore made a start himself, but he had very many difficulties to contend

* Reported on by Deyeux: Ann. Chim. Phys., 1799, *31*, 274. (Rapport fait à la classe des sciences mathématiques et physiques, le 6 thermidor, an 7; 24 July, 1799).

with. He had to compete with other factories working his own process, and with obvious advantages over himself. He no longer had a monopoly.

In July, 1801, he writes to one of his daughters: "My factory progresses in spite of many obstacles, which depend on the rapacity of the money-lenders. But I hope some time hence to do a profitably large trade .... I am again in a state of penury which does not permit me to do for you as I would." In September he was in good spirits and hopeful again. "You will find the factory in operation; I have made several charges of good soda, the Prefect of the Seine has samples of them for examination."* He was forced to borrow money, but with nothing to offer except the probable profits of his factory, he had to pay very high interest, and day by day the situation became worse, so that in 1803 he applied to the Société d'Encouragement for assistance, which, made him a grant of 2,000 fr. This was not enough to save him, nevertheless he still had sufficient courage and energy to attempt to retrieve his fortunes by turning his attention in the direction of the use of ammonium salts for manure.† But, although his scheme was favourably reported on by Vauquelin, Fourcroy and Deyeux, a patent he had applied for was not granted, and after this new disappointment he had thoughts of offering his inventions to the Russian Government. If he ever carried out his intention this also came to nothing, and he made one final effort to obtain adequate compensation from the Government. At last, in February, 1805, the Prefect of the Seine issued a decree submitting his document of 1803 to arbitration. Leblanc's calculations of losses due to confiscation of the factory, interruption of work during nearly seven years, loss of monopoly due to publication of his patent, and on the manufacture of sal ammoniac and white lead, amounted to about £100,000, and this, at a modest calculation. To this memorial were attached several declarations relating to these losses, of which one at least deserves to be mentioned. It was that of M. Payen and Debourlier who attested

* Anastasi, 97, 100.

† He published a report on the fabrication of ammonium chloride in Jour. de phys., 1800, *50*, 462.

that the process carried out in their soda factory, which was also situated in St. Denis, was that of Leblanc and was due entirely to the publication of the patent; "this statement being made," they said, "with the desire that the enlightened and excellent man to whom the process was due might profit by it." All honour to them! For ten months Leblanc had to wait as patiently as might be for the final decision of his fate. At length on 8th November, 1905, the report of the arbitrators was published. What Leblanc had valued at £100,000 they estimated at £4,660, of which Leblanc's share, after subtracting sums due to the Government on Orleans' account, would be about £2,000, the reward of twenty years' of toil and of the founding of one of the most important industrial processes of a whole century. The arbitrators could easily have afforded to be more generous, for nothing, even of their small award, was ever paid.

This final blow was more than Leblanc could bear. His powers diminished; he lost his fortitude; he became morose, and absorbed in his wrongs and his misfortunes; he deserted his laboratory and passed the day, and much of the night, in the constant writing of letters, petitions and memorials, but at last in the early morning of 16th February, 1806, he cut himself adrift from worldly cares by means of a pistol bullet. Leblanc, who had filled many public posts during the storm of the Revolution, who had placed all that he possessed at the service of his country, who had given to France a new and great industry; had been driven, through disappointment, to despair of human sympathy, pity and justice, and had sought relief on the other side of time.

Owing to the stirring events of the time his death passed unnoticed. His family was much reduced in circumstances and continued to make petitions to the authorities. His widow applied to Josèphine, "la mère des Français," but Josèphine, who had, perhaps, her own worries at home, took no notice. Another application furthered by friends, was made on 1st August, 1806, for payment of the indemnity, but this also was rejected. The restoration of the works was held to be sufficient.

Finally, the works were sold again and the money, 25,000 fr., given to Dizé, who had never expected anything from them, who was already well enough off, and who was willing to treat the memory of Leblanc so scurvily, that, in 1810, he published a historical account claiming the credit of Leblanc's discovery, a claim which was reported upon and rejected by La Rochefoucauld on 2nd September, 1819.* As late as 1852, Dizé published another note on the discovery of the method of preparing soda, again claiming the credit for it, but Leblanc's family on 17th November appealed to the Emperor (Napoleon III.) and all the necessary documents—the agreement between Leblanc and Dizé, the act of association, and the documents relating to Leblanc's patent—were handed to the Academy for investigation. On 30th November, 1855, Dizé's family at once made a counter-claim which was the cause of a thorough examination of the evidence, a review of the matter being published in the Comptes rendus (Sitting of 31st March, 1856), the report being made by Thénard, Chevreul, Pelouze, Regnault, Balard, and Dumas as secretary. This report was wholly in Leblanc's favour, and his claims would now be universally recognised. Hofmann, at the great Exhibition of London in 1862, spoke of "this man, who was certainly one of the greatest benefactors of humanity (who) lived in poverty and died of despair," and Dumas on the 23rd July, 1883, gave it as his opinion that "all that Leblanc has done can only be equalled by the discoveries of Watt in engineering. Of all men, the two who have done most for the welfare of mankind, are undoubtedly Leblanc and Watt."

Thus Leblanc received his reward in the end, and occupies henceforward an honoured niche in the temple of fame.

* Anastasi, p. 200.

Present-day Problems of the Atom and Radiation.

By Professor H. STANLEY ALLEN, M.A., D.Sc.

(*Read before the Society, 25th March,* 1925).

Many and varied are the ideas existing as to Science and also as to scientific investigators. The sarcastic words of Dr. Samuel Johnson will still serve to describe the attitude of many people:—"Some turn the wheel of electricity, some suspend rings to a loadstone, and find that what they did yesterday they can do again to-day. Some register the changes of the wind, and die fully convinced that the wind is changeable."

But the witty old doctor is even more severe:—"He that is growing great and happy by electrifying a bottle, wonders how the world can be engaged by trifling prattle about war or peace."

There are others who call themselves "practical" persons, who welcome Science for what they can gain from it. But the true worker in Science, like the true teacher, is—at least in his best moments—an idealist, not a materialist. As a foreign poet has well phrased it: "Knowledge is to some a goddess, to others only an excellent cow."

It is not always realised how important a part is played in scientific discovery by the two psychical factors, imagination and faith. Imagination is that power of the mind by which we picture that which is not actually presented to us by our senses. Faith is "a conviction of the reality of things which we do not see." Both these functions of mind and spirit must be exercised in an attempt to understand the problems presented by modern conceptions of the atom and radiation.

Here is a wooden disk, hard, rigid. To the sense of sight and touch there is nothing peculiar about it, by which it may be distinguished from any other disk of wood. But when I place one of the pair of projecting axles which it carries, on a suitable step ladder we find that the disk proceeds to walk, or rather roll, down the steps

in a slow and stately fashion, pausing on each step as though in doubt as to whether it shall continue its progress or not. The explanation is simple: the peculiar behaviour of the disk is due to a *concealed motion*; within it is a certain quantity of mercury which flows from one tubular chamber to another through a narrow orifice. After seeing the behaviour of this disk, constructed in the laboratory at St. Andrews under the direction of my predecessor, Professor A. S. Butler, we need not feel surprised when the natural philosopher tells us that the properties of matter may be explained by the motion of unseen particles.

Atomicity of Matter and Electricity.—Some twenty-five centuries ago the Greek philosopher Democritus was teaching that ordinary matter is made up of indestructible particles in constant motion. "The only existing things are the atoms and empty space; all else is mere opinion. The atoms are infinite in number and infinitely various in form; they strike together and the lateral motions and whirlings which thus arise are the beginnings of worlds." In 1717 Sir Isaac Newton wrote:—"It seems probable to me that God in the beginning formed Matter in solid, massy, hard, impenetrable, moveable particles."

The investigations of chemists during the nineteenth century gave precise form to the early speculations. Instead of an infinite variety of atoms it was found that only seventy varieties, the chemical "elements," hydrogen, helium, oxygen, copper, silver, and so forth, were necessary to build up, by means of their different combinations and groupings, the substances of the material world. When a substance is in the state of gas or vapour, the smallest particle which can move about as a whole, so that its parts (if it has any) do not part company is called a "molecule." Professor Peddie has recently drawn attention to an early and ingenious attempt made in Edinburgh by Sir John Leslie to determine the number of molecules in a grain of musk. A single grain of musk could scent for twenty years the often-renewed air of a large room. The conclusion was drawn that the grain must contain at least 320 quadrillions of particles (the usual British meaning of a quadrillion is a billion billions!) More recent

estimates agree well with those made by Lord Kelvin in Glasgow. About 500 million molecules placed in a straight line at their average distance apart in liquids would extend to a length of one inch.* A very striking illustration of the vast numbers involved may be quoted from Dr. Aston: "Take a tumbler of water and—supposing it possible—label all the molecules in it. Throw the water into the sea, or, indeed, anywhere you please, and after a period of time so great that all the water on the earth—in seas, lakes, rivers, and clouds—has had time to become perfectly mixed, fill your tumbler again at the nearest tap. How many of the labelled molecules are to be expected in it? The answer is, roughly, 2,000!" For although the number of tumblerfuls of water on the earth is enormous, the number of molecules of water in a single tumbler is about two thousand times greater.

After centuries of speculation as to the existence and nature of atoms, we now accept without hesitation an atomic theory of ordinary matter. In other words, solids, liquids and gases may be thought of as having a grained structure, being composed of the various atoms of the chemist. Many converging lines of experimental investigation justify the most cautious natural philosopher in regarding the atomic hypothesis as having been raised to the position of a well-founded scientific theory.

If, then, there is no dispute as to the discrete structure of matter, what are we to say of electricity? It was clearly recognised by the great master of electrical science, Michael Faraday, that the experimental facts which he discovered necessitated a similar view with regard to electrical charges. Faraday wrote in 1834:—" If we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalent to each other in their ordinary chemical action, have equal quantities of electricity naturally associated with them."

Here we have the first glimpse of an "atom of electricity," or as we now call it an " electron." Without entering into a metaphysical discussion of the meaning of physical reality, we may say that to the physicist the electron is just as "real" as is the atom to the chemist.

* According to the estimate in Mr. Gibson's Presidential Address (*Proceedings*, p. 62) the same number of dried peas placed in a straight line would stretch about 2,250 miles.

But the simplest experiments on electrification show that two kinds of electrified bodies must be considered. A glass rod rubbed with silk shows properties which may be ascribed to a vitreous or positive charge of electricity. An ebonite rod rubbed with fur is considered as possessing a resinous or negative charge. Two similar charges repel one another, two unlike charges attract one another. As a matter of history it was in connection with negative electricity that convincing evidence of atomic constitution was first given—in the experiments of J. J. Thomson and his fellow-workers from 1897 onwards. It was found possible to determine the charge carried by the "corpuscle" as J. J. Thomson termed the negatively electrified unit found, for example, in the "cathode rays" of a Crookes tube. It is well known, however, that equal and opposite quantities of electricity are produced in any electrical process—a rule without exception, which appears to hold with the greatest exactness. We should expect then positive electrons as well as negative electrons. In passing it may be remarked that no satisfactory explanation has yet been given of the essential differences between positive and negative electricity, or of the atomicity of electrical charges.

Let us picture (merely for convenience) a positive electron as a red ball, a negative electron as a blue ball. Then the atoms of the chemist are to be pictured as complex structures built up of red and blue balls, i.e., of discrete particles of positive and negative electricity. Consider the simplest atom, that of hydrogen. We may regard it as composed of one positive electron (or "proton," as Sir Ernest Rutherford has named it) and one negative electron (or "corpuscle.") If this picture is correct it must be noticed that, although the *charge* of the positive electron is numerically equal to that of the negative, the *mass* of the positive electron is about 1,840 times that of the negative, another highly remarkable fact requiring explanation.*

Since the two oppositely charged electrons attract one another it is clear that an atom composed of two such particles at rest at a

* It is here assumed that the positive electron is identical with the nucleus of the hydrogen atom, or proton. It is, of course, conceivable, that the proton itself is a complex structure built up of electrons of opposite sign but equal mass. But there is absolutely no evidence in favour of this view from the experimental side, whilst from the theorectical it introduces more difficulties than it removes.

finite distance apart would be unstable. There appear to be three possible ways of escape from this difficulty. We might suppose with Lord Kelvin that the positive charge is distributed throughout the volume of a sphere and that the smaller negative electron is at rest at the centre of the sphere. This view is now discarded though it has played an important part in the development of the subject in the hands of Sir J. J. Thomson, who employed the beautiful experiments of Mayer made with small floating magnets to show how a " model " atom may be constructed. In the second place we may introduce a second, hypothetical, force to balance the electrostatic attraction and so produce a " static model " of the hydrogen atom. This supposition has been used by Sir J. J. Thomson and by Irving Langmuir. At first sight this seems a very artificial hypothesis, but closer examination shows that it is not in reality more artificial than the third mode of escape which is that generally preferred at the present time. Indeed to mathematicians, who employ the method known as " the ignoration of co-ordinates," there may not appear to be much to choose between the two models which may be described as the " static " and the " dynamic " atom. In the dynamic atom temporary stability is produced by setting the negative electron rotating round the positive with high velocity, or more correctly speaking, setting both rotating round their common centre of gravity, just as in the case of the sun and a planet. According to the ordinary laws of electromagnetism such motion must be accompanied by the emission of energy in the form of electromagnetic waves, and the corpuscle would fall into the proton by a spiral path with ever increasing velocity. Such a system could not emit a spectrum consisting of a number of definite bright lines. The genius of Niels Bohr has boldly faced these difficulties by denying the universal validity of the classical electrodynamics, and by introducing certain postulates which constitute what is known as the Quantum Theory.

To complete our picture of an atom we are forced by experimental facts to accept the two main postulates of Bohr: (1) atomic systems can exist in certain " stationary states " which may be discussed by help of the ordinary electrodynamics in association with the appro-

priate quantum restrictions, (2) the passage of the systems between different stationary states cannot be treated by the classical theory, but involves, in some unexplained way, the emission or absorption of an amount of homogeneous radiation defined by the "energy quantum," which is the product of Planck's constant and the frequency of vibration.

These general statements may be made clearer by considering the simple case of the hydrogen atom. Here Bohr supposes that the single negative electron is circling round the positive nucleus in an orbit which may be described as a one-quantum orbit, a two-quantum orbit, and so on. Some of these orbits are circular, others are elliptical. In either case no radiation is emitted so long as the electron continues to move in a definite orbit. Radiation occurs when the electron in some unexplained manner jumps from one possible orbit to another of greater stability. In such a jump monochromatic radiation is emitted.

The atomic number of an element represents the number of these circling negative electrons which, together with an equal number of unit positive charges, constitutes an electrically neutral atom. The nucleus itself is complex and according to Rutherford is built up of positive hydrogen nuclei (or "protons") bound together by the requisite number of negative electrons. This return to Prout's hypothesis is supported by the very remarkable work of Aston carried out by means of the instrument which he calls a "mass spectrograph." Theoretically the very existence of such a nucleus implies the presence of enormous stores of energy, but in spite of exaggerated statements which have been published, there is at present no available method by which such energy can be liberated at will or controlled. Perhaps in the hottest stars we may be witnessing the transformation of simple elements such as hydrogen into complex atoms. The opposite process—the breaking up of atoms—is already known to us in the disintegration of the radioactive elements.

The Physical Significance of the Quantum.—The Quantum Theory indicates the existence of discontinuities in Nature of a kind not contemplated in the older mechanics. This atomicity may be

represented by Planck's constant, h, or by some combination of h with other fundamental constants. Planck's constant may be looked upon as a quantum of Action, though it is in some respects easier to regard it, in accordance with the suggestion of J. W. Nicholson as an angular momentum. The first indication of the magnetic character of the quantum appears in the work of S. B. M'Laren, published in part before the war, and now collected in a memorial volume published by the Cambridge University Press. M'Laren identified the natural unit of angular momentum $h/2\pi$, used by Bohr, with the angular momentum of the magneton. I have shown that this implies that the number of tubes of magnetic induction passing through the aperture of M'Laren's magneton is an integral number of times the fundamental magnitude, h/e, which may be called a quantum magnetic tube. A similar result appears to hold on the theory of Bohr, as was first pointed out in 1916 by A. L. Bernoulli, and has been shown by me to apply not only to circular but to elliptic orbits.

At the Edinburgh meeting of the British Association, Professor E. T. Whittaker pointed out that the ordinary electrostatic and magnetic tubes in three dimensions were dependent on the relative state of rest or motion of the observer, and went on to discuss the properties of electromagnetic tubes of force in four dimensions. Such a tube, or "calamoid," would involve both the electric and the magnetic vector and would satisfy all the requirements of the relativity theory. "Further, in the four-dimensional world it is action, not energy, which is conserved, so that the field appears open for a direct application of the quantum principle. The experimental physicist may feel somewhat appalled at the prospect of such a solution of his difficulties, but it may yet be necessary to invoke a four-dimensional tube of force as the unit brick from which a universe may be constructed."*

We proceed to consider further the details of this forecast.

The Four-Dimensional World of Minkowski.—In ordinary geometry we are accustomed to fix the position of a point in space by means of three co-ordinates. In the "space-time world" of Minkowski

* H. S. Allen, "Nature," vol. cviii., p. 341, 1921.

four co-ordinates are required to determine a " point-event," that is a specified moment and a specified place. Thus the point event is an element of the four-dimensional world as a point is an element of three-dimensional space. All observers will agree as to the magnitude of any "interval," that is the distance between two point-events in space-time, or in mathematical language the expression for the interval is " covariant." In the " world " of Minkowski " a geometry of four dimensions is used, not a mere combination of a three-dimensional space and a one-dimensional time, but a continuum of truly fourfold order. This time-space is not Euclidean, since the time-component and the three space-components are not on the same footing, but its fundamental formula has a great resemblance to that of Euclidean geometry." (W. de Sitter.)

Einstein in his General Theory of Relativity introduced a general non-Euclidean four-dimensional time-space, and enunciated his law of motion by saying :—" Particles which are not interfered with follow a geodesic line in the manifold." A geodesic in curved space or on a surface corresponds to a straight line in flat space. Larmor has laid stress on the application of the principle of Least Action in mechanical and electrodynamic problems. For example, an electron in moving through a magnetic field follows a geodesic line on a surface. It is this principle which led Einstein to his mode of stating the motion of bodies in space-time. The Quantum Theory may perhaps be thought of as providing the space-time world with certain partitions which impose restrictions on the motion of electrons or magnetons, which follow geodesic paths in accordance with the principles of minimum action. As de Sitter has expressed it :—" Our guiding idea (the impossibility of action at a distance) will prompt us to say, following the example of Faraday in his electrical researches, that the geodesics of a gravitational space have a physical existence as distinct from a mere mathematical one."*

" It must be pointed out that such things as length, velocity, energy, momentum, are not absolute, but relative, i.e., they are not attributes of the physical reality, but relations between this reality

* W. de Sitter, " Relativity and Gravitation," p. 286 (Methuen).

and the observer. Consequently the laws of conservation are not laws of the real world, like the law of gravitation, but of the observed phenomena. There is, however, one law which, already, before the days of relativity, had come to be considered as the most fundamental of all, viz., the principle of least action. Now, action is absolute. Accordingly this principle retains its central position in Einstein's theory. It is even more fundamental than the law of gravitation, since both this law, and the law of motion, can be derived from it. The principle of least action, so far as we can see at present, appears to be *the* law of the real world."*

The four-dimensional world is usually regarded as a continuum of points. For a line to be continuous there must be no gaps or holes in it. The same idea may be extended to space of two or three dimensions, and may be generalised so as to apply to any aggregate of elements numerically determined in such a way as to leave no holes. A set of elements of this kind forms a continuum. Now it is commonly assumed that the four-dimensional space-time world of Minkowski is a continuum, so that we pass from one element to another—from one event to another—by traversing a path involving " successive " events. But it is just here that the Quantum Theory introduces a difficulty. According to Poincaré† the hypothesis of quanta is the only hypothesis leading to the law of Planck, and it involves the following proposition:—" A physical system is only susceptible of a finite number of distinct states; it jumps from one of these states to another without passing through a continuous series of intermediate states."

It may be added that Poincaré has shown that no small, or even finite, departures from the formula of Planck will enable us to escape from such discontinuities. The necessity for discontinuity is bound up with the fact that the total radiation at a given temperature is finite and not infinite.

" Is discontinuity destined to reign over the physical universe, and will its triumph be final ? Or will it finally be recognised that

* W. de Sitter, " Relativity and Gravitation," Bird, p. 217 (Methuen).
† Poincaré, "Dernières pensées" (Flammarion, Paris, 1913), Jeans, Report on Radiation and the Quantum Theory.

this discontinuity is only apparent, and a disguise for a series of continuous processes? The first observer of a collision thought he was witnessing a discontinuous process, but we know to-day that what he saw was the result of changes which, although very rapid, were continuous."

It appears then that we may be compelled to look upon the four-dimensional world as essentially discontinuous in character. In three dimensions I have emphasised the suggestion that the Quantum Theory suggests the existence of discrete tubes of magnetic induction. Applying the same ideas to the four-dimensional tubes of force of Professor Whittaker, we are led to the view that the world of events is not a continuum, but is built up of individual tubes of force or "calamoids." In his recent Kelvin Lecture, Dr. Jeans has put this idea in picturesque form by saying that the Quantum Theory represents a quality of the four-dimensional continuum, which is somehow analagous to the scaliness of a crocodile skin.

"The final answer to any series of questions is inevitably—*because the world is so constructed.*" The final representation of the universe to which the Quantum Theory seems to point is a four-dimensional space-time world of events, in which unexpected (and perhaps in some respects undesirable) flaws or cracks are to be found. As the late Lord Rayleigh once remarked with reference to this very theory:—"It is not the question what we may like or dislike, but what the facts demand."

RULES GOVERNING THE COMPETITION FOR THE GRAHAM MEDAL.

1. The Competition for the Graham Medal shall be under the authority and control of the Council of the Royal Philosophical Society of Glasgow, whose decision on all matters connected therewith shall be final.

2. Each candidate shall forward to the Secretary of the Royal Philosophical Society of Glasgow, 207 Bath Street, Glasgow, on or before 14th February of the year in which the competition is held, a paper giving an account of an unpublished original research conducted by himself in any branch of chemical science, pure or applied.

3. The award shall be made to the candidate whose research, in the opinion of the Council, or of the person or persons whom they may appoint to adjudicate in the matter, is of the highest merit and most likely to aid in the advancement of chemical science.

4. The value of the award shall be £10, and, according to the wish of the successful candidate, may take the form of (i.) the Graham Medal in gold; (ii.) the Graham Medal in bronze, and scientific instruments or books; (iii.) the Graham Medal in bronze, and the balance in money to be applied in chemical research.

5. The paper, on account of which the medal is awarded, shall be read before the Royal Philosophical Society of Glasgow, and shall thereafter be published in the *Proceedings* of the Society.

6. No award shall be made if, in the opinion of the Council, no paper of sufficient merit has been offered.

MINUTES OF SESSION, 1924-1925.

8th October, 1924.

The First Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 8th October, 1924. The President, Mr. Charles R. Gibson, occupied the Chair.

1. An Address on "Lord Kelvin," in commemoration of the Centenary of his birth, was delivered by Sir J. Alfred Ewing, K.C.B., D.Sc., LL.D., F.R.S., Principal of the University of Edinburgh. Ten portraits of Lord Kelvin were shown on the screen, ranging from the age of 16 to the year before his death.

A vote of thanks was accorded to Sir Alfred on the motion of Principal Sir Donald Macalister, Bt., seconded by the President, who expressed his indebtedness to the good offices of Professor Archibald Barr in obtaining the consent of Sir Alfred to deliver the Centenary Address.

2. The following were elected to Membership:—

1. Mr. GEORGE W. ALEXANDER, 47 Melville Street, Pollokshields, Glasgow. Recommended by Mr. R. F. Smith, Mr. G. G. Braid, and Dr. R. M. Buchanan.
2. Mr. GEORGE PRATT INSH, M.A., D. Litt., 35 Camphill Avenue, Glasgow. Recommended by Prof. Bennett, Mr. Charles R. Gibson, and Professor James Muir.

Recommended by Mr. Charles R. Gibson, Dr. A. K. Chalmers, and Dr. R. M. Buchanan.

3. Bailie JAMES ARROL CRERAR, Garbhalt, Monreith Road, Newlands.
4. Mr. JAMES DUNLOP, M.B., C.M., 3 Seton Terrace, Dennistoun.
5. Mr. JOHN HENDERSON, M.D., 6 Newton Place, Glasgow.

Recommended by Mr. Charles R. Gibson, Prof. J. Graham Kerr, and Prof. James Muir.

6. Mr. D. C. STEWART BLACKLOCK, 49 Westbourne Gardens, Kelvinside.
7. Professor J. D. CURRIE, M.A., M.D., The University, Glasgow.
8. Mr. ARTHUR N. FORMAN, 160 Hope Street, Glasgow.
9. Mr. R. A. HOUSTOUN, M.A., D.Sc., Ph.D., Natural Philosophy Department, The University, Glasgow.
10. Mr. ROBERT M'LEAN, Auldfield House, Pollokshaws.
11. Mr. GEORGE L. PEACOCK, 111 Union Street, Glasgow.
12. Mr. ALEXANDER C. WHYTE, 26 Ravenshall Road, Shawlands.
13. Professor H. A. WILSON, D.Sc., F.R.S., 11 The University, Glasgow.

Recommended by Mr. William Gillies Niven, Mr. John F. Campbell, and Prof. Bennett.

14. Mr. WILLIAM MacMURRAY, 40 Kelvinside Gardens.

22nd October, 1924.

The Second Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 22nd October, 1924. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 8th October was approved and signed.

2. The New Members elected at last Meeting were duly admitted.

3. Dr. Henry J. Watt, Lecturer in Psychology, University of Glasgow, delivered a lecture on "Dreams." A discussion followed, and Dr. Watt received the thanks of the Meeting on the motion of Dr. Knight.

4. The following gentlemen were elected to Membership:—

1. Mr. WILLIAM ADAM, Works Chemist, 7 Oakfield Avenue, Hillhead, Glasgow. Recommended by Mr. William Graham, Professor Bennett and Mr. Charles R. Gibson.
2. Mr. JAMES ALEXANDER, 4 Walmer Terrace, Ibrox, Glasgow. Recommended by Mr. R. A. Burr, Dr. Farquhar MacRae, and Mr. Peter M. Cleland.
3. Captain G. GRANT FORMAN, The Lodge, Douglas Pier, Lochgoil. Recommended by Mr. Charles R. Gibson, Professor J. Graham Kerr and Professor James Muir.
4. Mr. WILLIAM GRAHAM, Junr., Plumber and Engineer, 3 Oakfield Avenue, Glasgow, W.2. Recommended by Mr. William Graham, Professor Bennett, and Mr. Charles R. Gibson.
5. Dr. ALLAN F. MILLER, 37 Lansdowne Crescent, Glasgow. Recommended by Dr. Lewis M'Millan, Mr. Charles R. Gibson, and Professor Bennett.

5th November, 1924.

The Third Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 5th November, 1924. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 22nd October was approved and signed.

2. The New Members elected at last Meeting were duly admitted.

3. Professor Thomas S. Patterson, D.Sc., Ph.D., University of Glasgow, delivered a lecture entitled "Soda, Nicolas Leblanc and the French Revolution," and received the thanks of the meeting on the motion of Mr. P. D. Ridge Beedle.

REPORT OF COUNCIL FOR 1923-1924.

I. *Meetings of the Society and Sections.*—Session 1923-1924 was opened on 10th October. 1923, by Sir Josiah C. Stamp, K.B.E., D.Sc., with an address on "The Capital Levy." Twelve Meetings of the Society were held at which thirteen papers were read, of which two were communications from the Economic Section Science and one from the Historical and Philological Section. Besides these, three papers were read before the Economic Science Section, six before the Historical and Philological Section, and five before the Biological Section. There was thus a programme of twenty-seven lectures provided for members of the Society.

II. *Papers read and not referred to elsewhere.*—(a) Before the Society: "The Electrical Structure of Matter," by J. A. Cranston, D.Sc., A.I.C.; "Scottish Education in the 18th Century," by Dr. William Boyd; "By-Products of the Glasgow Corporation Chemical Works," by Mr. William A. Walmsley, B.Sc.; "A Visit to Chinese Tibet," by Mr. C. J. Gregory, B.Sc.; (b) Before the Economic Science Section: "An 18th Century Highland Farm Account Book," by Miss I. F. Grant; "The Problem of Women's Wages," by Miss Janet N. R. Currie; (c) Before the Historical and Philological Section: "Scottish Families in Sweden," by Sir John S. Samuel; "The Interpretation of History," by Mr. David C. Douglas, M.A.; "Literature in School," by Mr. Alexander Haddow, M.A.; "Vicissitudes of Celtic Song," by Mr. Archd. N. Currie, M.A., B.Sc., A.I.C.; "Thomas Hardy," by Mr. Peter Alexander, M.A.; "Western Highlands at the beginning of the 17th Century," by Mr. Robert Bain; (d) Before the Biological Section: "Bacteriostatic Agents: Relationship between Biological Properties and Chemical Constitution," by Professor C. H. Browning, M.D.; "The Archenteric Canal in the Human Embryo and in other Mammals," by Professor Thomas H. Bryce, M.A., M.D.; "Insect Pests in Public Health Work," by Dr. R. M. Buchanan; "Notes on Plankton in the Firth of Clyde," by Miss M. Marshall, B.Sc.; "Hydrogen-ion Concentration and its Application to Laboratory Cultures," by Miss Monica Taylor, D.Sc.; "The Implantation of the Human Ovum and the Early Development of the Trophoblast," by Professor J. H. Teacher, M.D.

III. *The Proceedings.*—Vol. LII. of the *Proceedings* will be distributed to members shortly. The format has been entirely changed and, in every respect, improved. In conformity with the practice of the leading scientific Societies' future issues of the *Proceedings* will be in quarto.

IV. *Representation of the Society.*—The President was appointed to represent the Society at the Kelvin Centenary Celebrations held in London in July, and Professor E. P. Cathcart, M.D., D.Sc., F.R.S., was appointed the Society's Delegate at the Meeting of the British Association in Toronto.

PETER BENNETT, *Secretary.*

REPORT ON THE LIBRARY.

During the year ending 31st October no fewer than 82 volumes have been added to the Library, in addition to the usual scientific magazines and transactions which are on standing order. The additions include the geographical and political series, "Nations of To-Day," edited by John Buchan, the latest work in Egyptology and kindred subjects, and several works on atomic structure and the new physics generally, while the recent advances in physiology are represented by books on Vitamins and Endocrines.

The borrowers' ledger shows a steady interest on the part of members, but the Honorary Librarian would welcome a more extensive use of the Recommendation Book as an expression of the personal requirements of research students as well as a guide to the Committee.

JAMES KNIGHT, *Hon. Librarian.*

REPORT ON FINANCE.

The Honorary Treasurer's Statement for 1923-1924 shows that the ordinary revenue amounted to £857 7/-, and the ordinary expenditure to £987 18s. 11d., a deficiency of £130 11s. 11d. On the year's working, including extraordinary revenue, there is a surplus of £17 9s. 1d., compared with a deficit of £30 11s. 3d. for the year 1922-23. The Capital of the Society, as shown in the Balance Sheet, amounts to £6,741 9s. 1d., irrespective of the value of the library.

As formerly, separate statements are given showing the position of the two funds which the Society holds in trust, viz., The Graham Medal Fund and the Science Lectures Association Fund. The Capital of these two funds, as shown in the Abstract, is £195 3/- and £149 5s. 4d. respectively, the accumulation of revenue being £153 1s. 6d. and £81 12s. 10d. respectively.

REPORT ON MEMBERSHIP.

During the past session 37 Ordinary Members and 5 Life Members were elected. On the other hand, the names of 66 Members were removed by death or other causes.

The following is a list of the deaths so far as known:—William Anderson, Robert Angus, W. P. M. Black, J. Armour Brown, William Brown, Alexander Bruce, Sir Samuel Chisholm, A. Sykes Coubrough, Sir Kennedy Dalziel, W. G. K. Donaldson, John S. Galbraith, John Henderson, Dr. John Hutchison, Prof. William Jack, Rev. Alexander Kirkland, John T. Knox, Rt. Hon. A. Bonar Law, Robert Law, Dr. Edward M'Connell, Charles Macdonald, B. B. MacGeorge, William Maclay, George Millar, W. J. Mirrlees, George Murdoch, Dr. George Neilson, Robert Paterson, J. Hislop Pettigrew, William Renwick, James Salmon, R. H. Sinclair, J. Guthrie Smith.

ABSTRACT OF REVENUE AND

and comparison with

ORDINARY REVENUE.		1923-1924.	1922-1923.
		£ s. d.	£ s. d.
Subscriptions of 751 Members at £1 1s., - - - -		788 11 0	828 9 0
Revenue from Investments, - - - - -		51 0 5	53 11 9
Subscriptions of Associates of Sections—			
Economic Science, - - - - -	£6 0 0		
Historical and Philological, - - -	11 15 7		
Biological, - - - - - - - -	—	17 15 7	22 5 0
Note.—Accounts not received in time for inclusion in 1923-1924 Accounts.			
Deficit, - - - - - - - - -		130 11 11	146 2 6
		£987 18 11	£1050 8 3
EXTRAORDINARY REVENUE.			
Subscriptions—			
42 Entry Moneys, at One Guinea, - - - -		44 2 0	65 2 0
8 Life Subscriptions at Twelve Guineas, - -		100 16 0	63 0 0
1 Life Subscription at Three Guineas, - -		3 3 0	—
Improvements Fund—		—	443 15 7
Net Deficit for year carried to Capital A/c., - -		—	30 11 3
		£148 1 0	£602 8 10

EXPENDITURE—SESSION 1923-1924.

Session 1922-23.

ORDINARY EXPENDITURE.		1923-24.	1922-1923.
		£ s. d.	£ s. d.
Administration Expenses—			
Remuneration to Secretary, -	£200 0 0		
Allowance for Treasurer's Clerks, -	15 0 0		
Telephones, - - - - -	20 5 0		
Fire Insurance on Library, - -	17 5 0		
Postages and Sundry Charges, -	132 17 10		
		385 7 10	317 14 5
Expenses of Rooms—			
Upkeep and Service, £344 11 2			
Interest on Bond, - 127 17 11			
Lecture Expenses, - 6 1 4			
	£478 10 5		
Deduct—Rents received from other Societies, - - - - -	229 14 6		
		248 15 11	371 17 3
Library—			
New Books and Periodicals, British and Foreign Bookbinding, -	£95 6 10		
Subscriptions to Societies, - -	13 13 0		
		108 19 10	93 2 6
Printing—			
Printing of *Proceedings*, Circulars, etc., - -		225 0 1	253 18 11
Expenses of Sections per Secretaries—			
Economic Science, - - - - -	£5 8 8		
Historical and Philological, - - -	14 6 7		
		19 15 3	13 15 2
		£987 18 11	£1050 8 3
EXTRAORDINARY EXPENDITURE.			
Deficit brought down from Revenue and Expenditure Account, - - - - - - - - -		130 11 11	146 2 6
Improvements Fund—		—	456 6 4
Net Surplus for Year, carried to Capital A/c., - -		17 9 1	—
		£148 1 0	£602 8 10

Royal Philosophical Society of Glasgow.

BALANCE SHEET as at 31st AUGUST, 1924.

LIABILITIES.

	£	s.	d.	£	s.	d.
Bond—						
Over Buildings, at 5%, as per last A/c.,	£2750	0	0			
Repaid during year,	500	0	0			
				£2250	0	0
Accrued Charges,				329	11	9
Capital—						
At 31st August, 1923,	£6724	0	0			
Surplus to date per Extraordinary Revenue Account,	17	9	1			
				6741	9	1
				£9321	0	10

ASSETS.

	£	s.	d.	£	s.	d.
Buildings—						
207 Bath Street—Buildings and Furnishings, per last Account,				£7933	7	4
Library—						
Not valued,				0	0	0
Sundry A/cs. Outstanding,				29	10	3
Investments—						
£890 London, Midland & Scottish Rly. Co. 4% Debenture Stock,	£694	4	0			
£60 3½% Conversion Stock	44	11	0			
5% War Bonds, 1929,	250	0	0			
				988	15	0
Cash Balances—						
Clydesdale Bank, on Deposit Receipt,	£359	1	3			
In Curator's hands,	10	7	0			
				369	8	3
				£9321	0	10

Glasgow, 22nd October, 1924.—Examined and found correct.

JOHN MANN, C.A., *Honorary Treasurer.*

A. S. MACHARG, C.A.
HAROLD J. BLACK, } *Auditors.*

GRAHAM MEDAL AND LECTURE FUND.

ABSTRACT OF TREASURER'S ACCOUNT—Session 1923-1924.

Capital at 31st August, 1922, - -		£195 3 0
Revenue Accumulation to 31st August, 1923,	£126 7 7	
Dividends from L.M.& S. Railway Co., - -	10 11 11	
Interest on Deposit Receipt,	0 3 1	
Interest from Conversion Stock, - - -	2 16 0	
Income Tax Recovered, -	13 2 11	
		153 1 6
		£348 4 6

Investments		
£250 London, Midland & Scottish Railway Co., 4% Preference Stock in name of the Philosophical Society in trust, - -	£176 5 0	
Value of Die at H.M. Mint,	18 18 0	
		£195 3 0
Revenue Accumulation, per *contra*—		
£90 London, Midland & Scottish Railway Co., 4% Debenture Stock, -	£70 4 0	
£80, $3\frac{1}{2}$% Conversion Stock,	49 10 6	
Accrued Interest, - -	2 19 2	
Clydesdale Bank on Deposit Receipt, - -	30 7 10	
		153 1 6
		£348 4 6

Glasgow, 22nd October, 1924.—Examined and found correct.

A. S. MACHARG, C.A.
HAROLD J. BLACK. } *Auditors.*

JOHN MANN, C.A., *Honorary Treasurer.*

THE SCIENCE LECTURES ASSOCIATION FUND.

ABSTRACT OF TREASURER'S ACCOUNT—Session 1923-1924.

Capital at 31st August, 1923, - - - - - -				£149	5	4
Revenue Accumulations to 31st August, 1923, -	£71	9	3			
Dividends from L.M.&.S. Railway Co., -... - -	6	4	9			
Interest from Conversion Stock, - - - -	3	16	7			
Interest from Bank, - -	0	4	4			
Income Tax Recovered, -	12	18	4			
	£94	13	3			
Less Expenses of Lectures,	13	0	5			
				81	12	10
				£230	18	2

Investments—						
£200 London, Midland & Scottish Railway Co., 4% Preference Stock, in name of the Philosophical Society, in trust, -	£141	0	0			
In Bank, on Deposit Receipt,	8	5	4			
				£149	5	4
Revenue Accumulations, per *contra*—						
£100 3½% Conversion Stock,	£61	14	8			
Accrued Interest, -	2	10	3			
In Bank on Deposit Receipt,	17	4	11			
Cash in hands of Treasurer,	0	3	0			
				81	12	10
				£230	18	2

Glasgow, 24th October, 1924.—Examined and found correct.

A. S. MACHARG, C.A.
HAROLD J. BLACK. } *Auditors.*

JOHN MANN, C.A., *Honorary Treasurer.*

20th November, 1924.

The Fourth Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Thursday, 20th November, 1924. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 5th November was approved and signed.

2. The Annual Reports and Abstracts of Accounts were adopted on the motion of the Chairman.

3. Votes of thanks were accorded to:—

(i.) The Hon. Treasurer, Sir John Mann, on the motion of Mr. R. A. Burr.

(ii.) The Hon. Librarian, Dr. James Knight, on the motion of Mr. William Fraser.

(iii.) The Auditors, Mr. A. S. Macharg, C.A., and Mr. Harold J. Black, on the motion of the President.

(iv.) The Donors of Books, on the motion of the President.

4. Lord Montagu of Beaulieu delivered a lecture entitled "Roads and Road Transport." A discussion followed and the lecturer was accorded a vote of thanks.

5. The following gentlemen were elected to Membership:—

1. Mr. THOMAS DUNLOP, Jr., 70 Wellington Street, Glasgow. Recommended by Mr. David Sclanders, Mr. Charles R. Gibson, and Professor Bennett.
2. Mr. WILLIAM DUNN, Strathyre, Busby Road, Giffnock. Recommended by Dr. William Gillies, Mr. James Murdoch, and Professor Bennett.
3. The Rev. ROBERT HUGHES, Ph.D., B.D., Rector of St. David's, Lime Grove, Manchester, 62 Park Street, Greenheys, Manchester. Recommended by Mr. Charles R. Gibson, Professor Bennett, and Dr. Charles Bennett.
4. Mr. R. GRAHAME MURDOCH, 20 Woodlands Terrace, Glasgow. Recommended by Mr. James Murdoch, Mr. Charles R. Gibson, and Dr. William Gillies.

3rd December, 1924.

The Fifth Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 3rd December, 1924. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 20th November was approved and signed.

2. The New Members elected at last Meeting were duly admitted.

3. Professor Ralph Stockman, M.D., University of Glasgow, delivered a lecture entitled "Ancient and Modern Medicine." A discussion followed, and the lecturer was accorded the thanks of the Meeting.

4. The following gentlemen were elected to Membership:—

1. Mr. FRANK R. BURNET, Architect, Enterkin, Kilmacolm. Recommended by Mr. William Fraser, Mr. Charles R. Gibson, and Professor Bennett.
2. Mr. PERCY C. HARRISON, Surveyor, 40 Cochrane Street, Glasgow. Recommended by Mr. William Fraser, Mr. Charles R. Gibson, and Mr. Andrew Muir.

3. Mr. ALEXANDER W. H. HEDDERWICK, Stockbroker, 79 St. George's Place, Glasgow. Recommended by Mr. Charles R. Gibson, Dr. Gillies, and Mr. James Murdoch.
4. Mr. J. CASSELS PINKERTON, B.L., Rating Surveyor, 40 Cochrane Street, Glasgow. Recommended by Mr. William Fraser, Mr. Charles R. Gibson, and Mr. Andrew Muir.
5. Mr. JOHN SHARP, M.I., Mech.E., 28 Burnbank Gardens. Recommended by Mr. William Fraser, Mr. Charles R. Gibson, and Professor Bennett.

17th December, 1924.

The Sixth Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 17th December, 1924. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 3rd December was approved and signed.

2. The New Members elected at last Meeting were duly admitted.

3. Professor R. M. Caven, D.Sc., F.I.C., Royal Technical College, delivered a lecture, with lantern illustrations, on "The Atomic Theory in Ancient and Modern Days." A discussion followed, and a vote of thanks was accorded to the Lecturer on the motion of Professor T. S. Patterson.

14th January, 1925.

The Seventh Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 14th January, 1925. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 17th December was approved and signed.

2. The President, Mr. Charles R. Gibson, F.R.S.E., delivered his Presidential Address on "The Evolution of Electrical Knowledge": a bird's eye view of how our knowledge of Electricity has come about. The address was illustrated by experiments. A vote of thanks was accorded to the President on the motion of Mr. P. D. Ridge Beedle, and on the motion of the President votes of thanks were passed to Professor James Muir and his assistant, Mr. Smith, who had given valuable service in connection with the experiments.

28th January, 1925.

The Eighth Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 28th January, 1925. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 14th January was approved and signed.

2. Professor T. Parker Smith, D.Sc., M.I.E.E., A.M.Inst.C.E., Royal Technical College, delivered a Lecture (illustrated by experiments and lantern slides) on "An Electric House." A discussion followed, and the Lecturer was accorded a vote of thanks on the motion of Mr. George G. Braid.

3. The following were duly elected to Membership:—

1. Mr. JOHN DICKSON, Amisfield, Monreith Road, Newlands, Glasgow. Recommended by Mr. Charles R. Gibson, Professor Graham Kerr, and Professor James Muir.
2. Mr. B. HAGUE, M.Sc., A.M.I.E.E., 13 Ruthven Street, Hillhead, Glasgow. Recommended by Mr. George G. Braid, Professor J. Parker Smith, and Professor G. W. O. Howe.
3. Mr. HAROLD J. MACLEISH, C.A., 116 Hope Street, Glasgow. Recommended by Mr. P. D. Ridge-Beedle, Mr. Charles R. Gibson, and Sheriff Thomson.

11th February, 1925.

The Ninth Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 11th February, 1925. Mr. P. D. Ridge-Beedle, Vice-President, occupied the Chair, but leaving before the close of the Meeting, Dr. John Edwards presided during the remainder of the evening.

1. The Minute of Meeting of 28th January was approved and signed.
2. The New Members elected at last Meeting were duly admitted.
3. Professor R. S. Rait, C.B.E., LL.D., Historiographer Royal for Scotland, delivered a lecture on " King James and his Mother, Queen Mary." A vote of thanks was accorded to the Lecturer on the motion of the Chairman, Dr. Edwards.

25th February, 1925.

The Tenth Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 25th February, 1925. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 11th February was approved and signed.
2. Professor D. Noel Paton, M.D., F.R.S., University of Glasgow, delivered a lecture on "Vitalism." A discussion followed and on the motion of Professor Caven a vote of thanks was accorded to the Lecturer.
3. The following gentlemen were duly elected to Membership:—

1. Mr. JOHN CRAIG, The Moorings, Motherwell. Recommended by Mr. P. D. Ridge-Beedle, Dr. John Edwards, and Dr. William Gillies.
2. Mr. R. A. McLEAN, Monkton Miln, Ayrshire. Recommended by Mr. Charles R. Gibson, Mr. George W. Service, and Professor James Muir.

11th March, 1925.

The Eleventh Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 11th March, 1925. The President, Mr. Charles R. Gibson, occupied the chair.

1. The Minute of Meeting of 25th February was approved and signed.
2. The New Members elected at last Meeting were duly admitted.

3. Mr. F. F. P. Bisacre, M.A., B.Sc., delivered a lecture, with lantern illustrations, entitled " The Electrification of Railways around Glasgow." A discussion followed, and a vote of thanks was accorded to the Lecturer on the motion of Professor S. Parker Smith.

25th March, 1925.

The Twelfth and last Meeting of the Society for Session 1924-1925 was held in the Rooms, 207 Bath Street, on Wednesday, 25th March, 1925. The President, Mr. Charles R. Gibson, occupied the Chair.

1. The Minute of Meeting of 11th March was approved and signed.

2. Professor H. Stanley Allen, M.A., D.Sc., University of St. Andrews, delivered a lecture, illustrated by experiments and lantern slides, on " Present-day Problems of the Atom and Radiation." A discussion followed, and a vote of thanks was accorded to Professor Allen on the motion of Professor H. A. Wilson.

3. The following gentlemen were elected to Membership :

RECOMMENDED BY THE COUNCIL.

Honorary Members.

1. Professor HENRY E. ARMSTRONG, Ph.D., LL.D., D.Sc., F.R.S. (Past President of the Chemical Society), 55 Granville Park, Lewsham, London, S.E.
2. Sir JAMES GEORGE FRAZER, O.M., D.C.L., LL.D., Litt.D., F.R.S., F.B.A., Trinity College, Cambridge.
3. Professor ANDREW GRAY, M.A., D.Sc., LL.D., F.R.S. (Emeritus Professor of Natural Philosophy, University of Glasgow), The University, Glasgow.

Corresponding Members.

1. Professor FREDERICK SODDY, M.A., F.R.S. (Professor of Inorganic and Physical Chemistry, University of Oxford), 131 Banbury Road, Oxford.
2. Sir JAMES WALKER, Ph.D., D.Sc., LL.D., F.R.S. (Past President of the Chemical Society), 5 Wester Coates Road, Edinburgh.

Ordinary Members.

1. Mr. HENRY BERTRAM, LL.B., 13 Newlands Road, Newlands. Recommended by Mr. Charles R. Gibson, Professor J. Graham Kerr, and Professor James Muir.
2. Mr. GEORGE BLATCH, Banker, 34 Lawrence Street, Dowanhill, Glasgow. Recommended by Mr. P. D. Ridge-Beedle, Mr. Charles R. Gibson, and Mr. David Sclanders.
3. Mr. W. G. GRAY, Company Director, Drusay, Bearsden. Recommended by Mr. P. D. Ridge-Beedle, Mr. Charles R. Gibson, and Professor Bennett.

4. The President announced that the following gentlemen had, in accordance with the Articles of Association, been elected to fill the offices in the Council falling vacant by retirals at this time : President, Professor J. Graham Kerr, M.A., F.R.S. ; Vice-President, Professor G. G. Henderson, D.Sc., LL.D., F.R.S. ; Members of Council, Professor T. S. Patterson, D.Sc., Ph.D., Col. Archibald Arrol Kennedy, D.S.O., O.B.E., Dr. Henry L. G. Leask, F.R.F.P.S.G., and Mr. George Wingate, C.A. ; Hon. Librarian, Dr. James Knight ; Hon. Treasurer, Sir John Mann ; Auditors, Mr. A. Murray Gourlay, C.A., and Mr. Alexander Watson, C.A.

5. On the motion of Mr. P. D. Ridge-Beedle, seconded by Mr. David Sclanders, a vote of thanks was accorded to Mr. Charles R. Gibson, the retiring President, for his valuable services to the Society during his three years' tenure of office. It was stated that of the new members elected during his Presidentship, the greater number were introduced by Mr. Gibson himself. Reference was also made to the success of the Improvements Fund, initiated and organised by him, whereby about £480 was raised by voluntary subscriptions of members and spent in needed renovation of the Rooms and the installation of several modern appliances for general convenience.

The President replied, and on his motion a vote of thanks was passed to the other retiring members of Council.

6. This minute was read by the Secretary and adopted, and the President was authorised to sign it.

ACKNOWLEDGMENTS.

55 Granville Park,
Lewisham, London, S.E. 13.
March 30, 1925.

The Secretary,
The Royal Philosophical Society of Glasgow.

Dear Sir,

I have to-day received your favour of the 28th, informing me that The Royal Philosophical Society of Glasgow has elected me an Honorary Member.

Will you please convey my most grateful thanks to your Council.

The honour is one which gives me peculiar pleasure, as an official connexion with Scottish science, so specially before chemists in the names of Black, Graham, Playfair, Young, Dewar, and Crum Brown.

Yours faithfully,

HENRY E. ARMSTRONG.

Trinity College,
Cambridge.
30th March, 1925.

Dear Sir,

I thank you for your kind and courteous letter received to-day. I much appreciate the honour done me by The Royal Philosophical Society of Glasgow in electing me an Honorary Member, and I gratefully accept the election. The very kind and graceful terms in which, in the name of the Society, you speak of my work, add much to my pleasure in joining The Royal Philosophical Society of my native city, the city where I received my earliest school education, and where, in after years, at the University I was first interested in philosophy.

I beg that you will convey to the Society my most grateful thanks for the high honour they have done me, and that you will accept for yourself my thanks for your courteous letter.

Believe me, Dear Sir,

Yours very gratefully and sincerely,

JAMES GEORGE FRAZER.

To Peter Bennett, Esq.,
Secretary,
The Royal Philosophical Society of Glasgow.

Department of Applied Physics,
The University,
Glasgow.
March 31, 1925.

My Dear Professor Bennett,

On behalf of my father I desire to acknowledge receipt of your letter, dated March 27. My father appreciates highly the great honour done him by the Council of The Royal Philosophical Society of Glasgow. He is very glad that the letter was drafted by an old friend and comrade.

I am,

Yours very sincerely,

J. G. GRAY.

131 Banbury Road,
Oxford.
April 11*th*, 1925.

The Secretary,
Royal Philosophical Society, Glasgow.

Dear Mr. Bennett,

I have been away from home and have just received your letter of 28th March, conveying to me the news of my election as a Corresponding Member of The Royal Philosophical Society of Glasgow. Please convey to the Society my appreciation of the honour they have conferred upon me and the great pleasure it gives me to be more closely associated with the Glasgow Royal Philosophical Society, of which I retain many memories from the time I was an ordinary member.

Yours sincerely,

FREDERICK SODDY.

Palace Hotel,
Barcelona.
14*th April*, 1925.

Peter Bennett, Esq.,
Secretary,
Royal Philosophical Society, Glasgow.

Dear Sir,

As I have been on the move in Spain, your letter of 28th March only reached me yesterday. Please accept my best thanks for it, and kindly convey to the Council the expression of my sincere gratitude for the honour they have done me in electing me a Corresponding Member of the Society, an honour which I greatly appreciate.

Yours very truly,

JAMES WALKER.

OFFICE-BEARERS
OF THE
Royal Philosophical Society of Glasgow.

SESSION 1924-1925.

President.
*CHARLES R. GIBSON, F.R.S.E.

Vice-Presidents.
Sir ROBERT BRUCE, LL.D.
Mr. P. D, RIDGE BEEDLE.
*Professor G. G. HENDERSON, D.Sc., LL.D., F.R.S.

Honorary Vice-Presidents.
Professor JOHN GRAY M'KENDRICK, M.D., LL.D., F.R.S., F.R.S.E., F.R.C.P.E.
Professor ARCHIBALD BARR, D.Sc., LL.D., M.Inst. C.E.
DAVID MURRAY, M.A., LL.D., F.S.A.
FREELAND FERGUS, M.D., LL.D., F.R.F.P.S.G., F.R.S.E.
Professor JOHN GLAISTER, M.D., F.R.F.P.S.G., D.P.H. (Camb.), F.R.S.E., F.C.S.
JOHN EDWARDS, LL.D., F.R.S.E., F.S.A.
WILLIAM GILLIES, LL.D., F.S.A.
JAMES KNIGHT, M.A., D.Sc., F.R.S.E., *Hon Librarian.*
Sir JOHN MANN, C.A., *Hon. Treasurer.*
Professor PETER BENNETT, *Secretary.*

Presidents of Sections.
Professor W. R. SCOTT, D.Phil., Litt.D., *Economic Science Section.*
Professor THOMAS H. BRYCE, M.A., M.D., *Biological Section.*
RICHARD MURRAY, M.A., *Historical and Philological Section.*

Other Members of Council.

*Hugh R. Buchanan, LL.B., S.S.C.
*James Murdoch.
*John Dallas.
*W. R. Baxter.
William A. Walmsley, B.Sc.
Sheriff A. S. D. Thomson.
David Sclanders.
Daniel Browning.
N. Paton Brown.
James Macfarlane, LL.D.
Robert A. Burr, M.A,, B.Sc.
William Fraser, F.S.I.

**Retire by rotation on April*, 1925.

THE ROYAL PHILOSOPHICAL SOCIETY EXCHANGES WITH THE FOLLOWING SOCIETIES, Etc. :—

AFRICA.

Cape Town—
Cape of Good Hope Observatory, The Astronomer Royal.
South African Philosophical Society.

Johannesburg—
South African Association for the Advancement of Science.

Pretoria—
Transvaal Department of Agriculture.

AUSTRALIA.

Brisbane—
Royal Geographical Society of Australasia.

Melbourne—
Royal Observatory Library.
Royal Society of Victoria, Victoria Street.

Sydney—
Geological Survey, Department of Mines and Agriculture.
Royal Society of New South Wales, 5 Elizabeth Street, North.
Technological Museum.
Royal Anthropological Society of Australasia.
Australian Association for the Advancement of Science. The University.
Australian Museum.
University Library.

BELGIUM.

Brussels—
Académie Royale des Sciences.
Observatoire Royale.
Société Royale Malacologique de Belgique. 14 Rue des Sols.

Liége—
Société Royale des Sciences.

BRAZIL.

Rio de Janeiro—
Museu Nacional de Rio de Janeiro.

CANADA.

Guelph (Ont.)—
Entomological Society of Ontario.

Halifax—
Nova Scotian Institute of Science.

Hamilton (Ont.)—
Hamilton Association.

Montreal—
Canadian Society of Civil Engineers. 112 Mansfield Street.

Ottawa—
Geological Survey of Canada, Sussex Street.
Royal Society of Canada.

Quebec—
Literary and Historical Society of Quebec.

Regina—
Department of Agriculture, North-West Territories.

Toronto—
Canadian Institute, 58 Richmond Street, East.

Winnipeg—
Manitoba Historical and Scientific Society.

CHINA.

Hong Kong—
Hong Kong Observatory.

ENGLAND AND WALES.

Barnsley—
Midland Institute of Mining, Civil, and Mechanical Engineers, Elder Street.

Bath—
Bath Natural History and Antiquarian Field Club. Royal Literary Institution.

ENGLAND AND WALES—*continued.*

Birmingham—
Philosophical Society, Medical Institute, Edmund Street.

Bristol—
Bristol Naturalists' Society. Dr. C. K. Rudge, Ashgrove House, 145 White Ladies' Road, Clifton.

Cambridge—
Philosophical Society, New Museum.
University Library. The Curator.

Cardiff—
Cardiff Naturalists' Society. Dr. Griffith, 50 Newport Road.
South Wales Institute of Engineers, Park Place.

Falmouth—
Royal Cornwall Polytechnic Society.

Greenwich—
Royal Observatory. The Astronomer Royal.

Leicester—
Leicester Literary and Philosophical Society.

Liverpool—
Geological Society, Royal Institution, Colquitt Street.
Literary and Philosophical Society. Tate Librarian, University College.
Liverpool Engineering Society, Royal Institution, Colquitt Street.

London—
Anthropological Institute, 3 Hanover Square.
British Association for the Advancement of Science, Burlington House.
British Museum. The Superintendent, Copyright Office.
British Museum. Natural History Department, Cromwell Road.
Chemical Society, Burlington House.
Electrical Publishing Co., Ltd., 4 Southampton Row, Holborn, W.C.
Engineering. The Publisher, 35 Bedford Street, Strand.
Engineering Review Co., 104 High Holborn ,W.C.
Institution of Civil Engineers, Great George Street, Westminster, S.W.
Institution of Mechanical Engineers, Storey's Gate, St. James' Park, Westminster.
Junior Institution of Engineers, 39 Victoria Street, Westminster, S.W.

ENGLAND AND WALES—*continued.*

Patent Office Library, 25 Southampton Buildings, Chancery Lane.
Pharmaceutical Society, 17 Bloomsbury Square.
Royal Geographical Society, 1 Saville Row, Burlington Gardens, W.
Royal Institute of British Architects, 9 Conduit Street, Hanover Square.
Royal Institution of Great Britain and Ireland, Albemarle Street, Piccadilly, W.
Royal Meteorological Society, 22 Great George Street, Westminster.
Royal Photographic Society, 66 Russell Square, W.
Royal Society, Burlington House.
Royal Statistical Society, 9 Adelphi Terrace, Strand.
Society of Arts, John Street, Adelphi.
Society of Biblical Archaeology, 37 Great Russell Street, Bloomsbury.
Society of Chemical Industry, Palace Chambers, 9 Bridge Street, Westminster.

Manchester—
Geographical Society, 16 St. Mary's Parsonage.
Literary and Philsophical Society of Manchester, 36 George Street.

Middlesborough—
Cleveland Institution of Engineers, Corporation Road.

Newcastle-upon-Tyne—
North-East Coast Institution of Engineers and Shipbuilders, 4 St. Nicholas Buildings.
North of England Institute of Mining and Mechanical Engineers, Neville Hall.

Oxford—
Bodleian Library.

Stratford (Essex)—
Essex Field Club. Essex Museum of Natural History, Romford Road.

Truro—
Royal Institution of Cornwall.

Watford—
Hertfordshire Natural History Society and Field Club, Upton House.

Welshpool—
Powys-Land Club. The Secretaries, Museum and Library, Salop Road.

FRANCE.

Bordeaux—
Société des Sciences Physiques et Naturelles de Bordeaux.

FRANCE—*continued.*

Marseilles—
Faculté des Sciences de Marseille.

Paris—
Ecole Polytechnique. The Director.
Observatoire Météorologique Central de Montsouris.

Rennes—
Library of the University.

GERMANY.

Berlin—
Deutsche Chemische Gesellschaft.
Deutsche Kolonial-Verein.
Königliche Preussische Akademie der Wissenchaften.

Giessen (Hesse)—
Oberhessische Gesellschaft fur Natur-und-Heilkunde.

Griefswald (Prussia)—
Geographische Gesellschaft.

Halle (Prussia)—
Vereins fur Erdkunde zu Halle.
Kaiserliche Leopoldino-Carolinische Deutsche Akademie der Naturforscher.

INDIA.

Calcutta—
Geological Survey of India.

IRELAND.

Belfast—
Belfast Naturalists' Field Club, Museum, College Square, North.
Natural History and Philosophical Society, Museum, College Square, North.

Dublin—
Royal Dublin Society, Leinster House.
Royal Irish Academy, 19 Dawson Street.
Trinity College Library.

ITALY.

Milan—
Reale Instituto de Lombardo di Science, Lettere, ed Arti.

JAPAN.

Kyoto—
Imperial University ,College of Science and Engineering.

Tokio—
Imperial University of Tokio, Science College.

JAVA.

Batavia—
Royal Magnetical and Meteorological Observatory.

MEXICO.

Mexico—
Instituto Geologico de Mexico.
Observatorio Astronomico Nacional de Tacubaya.
Observatorio Meteorologico-Magnetico Central.
Sociedad Científica " Antonio Alzate."

MONACO.

Monaco—
Musée Océanographique.

NETHERLANDS.

Amsterdam—
Adadémie Royale des Sciences à Amsterdam.

Haarlem—
Musée Teyler.
Société Hollandaise des Sciences à Haarlem.

Leyden—
Kon. Nederlandisch Aardrijkskundig Genootschap

NEW ZEALAND.

Wellington—
New Zealand Institute.

NORWAY.

Oslo—

Kongelige Norske Frederiks Universitet.
Videnskabs-Selskabet i Oslo.

ROUMANIA.

Bucharest—

Societatii de Sciinte Fizice.

RUSSIA.

Kazan—

Imperial Kazan University.

St. Petersburg—

Académie Impériale des Sciences.

SCOTLAND.

Aberdeen—

Philosophical Society, 147 Union Street.

Alnwick—

Berwickshire Naturalists' Club. W. J. Bolam, Berwick-on-Tweed, *per* George Bolam.

Edinburgh—

Advocates' Library.
Botanical Society of Edinburgh, Royal Botanic Garden.
Geological Society, 5 St. Andrew's Square.
Highland and Agricultural Society of Scotland, 3 George IV. Bridge.
Royal Physical Society, 1 India Buildings.
Royal Scottish Geographical Society, Queen Street.
Scottish Meteorological Society, 122 George Street.
Royal Scottish Society of Arts, 117 George Street.
Royal Society, George Street.
Scottish Board of Agriculture, St. Andrew's Square.

Glasgow—

Archaeological Society, 88 West Regent Street.
Baillie's Institution Free Library.
Faculty of Physicians and Surgeons of Glasgow, 242 St. Vincent Street.
Geological Society, 207 Bath Street.
Glasgow University.
Glasgow and West of Scotland Technical College Library.

SCOTLAND—*continued.*

Glasgow (*continued*)—

Institute of Accountants and Actuaries in Glasgow.
Institute of Engineers and Shipbuilders in Scotland, Elmbank Street.
Mitchell Library, North Street.
Natural History Society of Glasgow, 207 Bath Street.
Stirling's Public Library, Miller Street.
West of Scotland Iron and Steel Institute.

Hamilton—

Mining Institute of Scotland.

SWEDEN.

Upsala—

Royal University Library.

Stockholm—

Kongliga Svenska Vetenskaps-Akademie.

TASMANIA.

Hobart

Royal Society of Tasmania.

UNITED STATES.

Albany—

New York State Department of Health.
New York State Library.

Austin (Texas)—

Texas Academy of Science.

Baltimore—

Johns Hopkins University.

Berkeley (Cal.)—

University of California. Exchange Department University Library.

Boston—

American Academy of Arts and Sciences.
Boston Society of Natural History.
Library of the City of Boston, Copley Square.

Buffalo—

Buffalo Society of Natural Sciences.

Chicago—
Western Society of Engineers.

Colorado Springs—
Coburn Library, Colorado College.

Columbia (Mo.)—
University of Missouri. The Librarian.

Davenport (Iowa)—
Academy of Natural Sciences.

Denver—
Colorado Scientific Society.

Des Moines (Iowa)—
Iowa Geological Society.

Indianapolis (Ind.)—
Indiana Academy of Science.

Lawrence (Kansas)—
Kansas University.
Columbus.
Ohio State University.

Madison (Wis.)—
Madison Geological and Natural History Society.
Washburn Observatory.

Mount Hamilton (Cal.)—
Lick Observatory.

Newhaven (Conn.)—
Connecticut Academy of Arts and Sciences.
Yale University.

New York—
American Geographical Society, 15 Eighty-first Street.
Anerican Museum of Natural History, Seventy-seventh Street, and Central Park West.
American Society of Civil Engineers, 220 West Fifty-seventh Street.
New York Public Library, 40 Lafayette Place.
New York Academy of Sciences Library, Seventy-seventh Street, Central Park, West.
School of Mines, Columbia College. The Associate Editor.

Philadelphia—

Academy of Natural Science of Philadelphia.

The Associated Alumni of the Central High School of Philadelphia.

American Pharmaceutical Association.

American Philosophical Society. The Hon. Secretaries, 104 South Fifth Street.

Franklin Institute, 15 South Seventh Street.

Numismatic and Antiquarian Society of Philadelphia.

Wagner Free Institute of Science, corner of Seventeenth Street and Montgomery Avenue.

Rochester (N.Y.)—

Rochester Academy of Science. Corresponding Secretary.

St. Louis (Mo.)—

Academy of Science of St. Louis, 3817 Olive Street.

Missouri Botanical Garden.

Salem—

American Association for the Advancement of Science.

San Francisco (California)—

California Academy of Sciences.

Topeka (Kansas)—

Kansas Academy of Science.

Washington—

Bureau of Education (Department of the Interior).

Bureau of Ethnology.

Smithsonian Institution.

United States Geological Survey.

United States National Museum (Department of the Interior).

United States Naval Observatory.

United States (Department of Agriculture).

Volta Bureau.

LIST OF PERIODICALS.

(Those received in exchange are indicated by an "a.")

WEEKLY.

Academy.
Architect.
Athenaeum.
British Journal of Photography.
Builder.
Building News.
Chemical News.
Comptes Rendus.
County and Municipal Record.
*a*Deutsche Kolonialzeitung.
Dingler's Polytechnisches Journal.
Electrical Review.
Electrician.
*a*Engineering.
English Mechanic.
*a*Illustrated Official Journal of Abridgments.
*a*Journal of the Society of Arts.
Knowledge.
Lancet.
La Nature.
Nature.
Notes and Queries.
Science.
Scientific American and Supplement.
Times, Literary Supplement.
Zeitschrift für Angewandte Chemie.

FORTNIGHTLY.

*a*Berichte der Deutschen Chemischen Gesellschaft.
Journal de Pharmacie et de Chimie.

MONTHLY.

Agricultural Economist and Horticultural Review.
American Journal of Science.
Analyst.
Annales de l'Institut Pasteur.
Annals and Magazine of Natural History.
Bulletin de la Société d'Encouragement pour l'Industrie Nationale.
Bulletin of the Scottish Department of Agriculture.
*a*Canadian Entomologist.
*a*Engineering Review.
*a*Geographical Journal.
Geological Magazine.
*a*Johns Hopkins University Circulars.
Journal of Botany.
*a*Journal of the Chemical Society.
Journal of Education.
*a*Journal of the Franklin Institute.
*a*Journal of the Royal Photographic Society.
*a*Journal of the Society of Chemical Industry.
*a*Journal of the Western Society of Engineers.
Library Association Record.
Library World.
London, Edinburgh, and Dublin Philosophical Magazine.
Positivist Review.
*a*Proceedings of the Royal Society of London.

MONTHLY—*continued.*

*a*Proceedings of the Society of Biblical Archaeology.
Revue Universelle des Mines.
*a*Royal Astronomical Society's Monthly Notices.
Science Abstracts.
*a*Science of Man.
*a*Scottish Geographical Magazine.
*a*Sitzungsberichte der Königlichen Preussischen Akademie der Wissenschaften zu Berlin.
*a*Tijdschrift van het Koninklijk Nederlandoch Aardrijkskundig Genootschap.
Zeitschrift fur Analytische Chemie.

QUARTERLY.

Annals of Botany.
*a*Annals of Scottish Natural History.
*a*Archives Néerlandaises des Sciences Exactes et Naturelles.
*a*Bulletin of the American Geographical Society.
*a*Bulletin of the Kansas University.
Economic Journal.
English Historical Review.
Journal of Anatomy and Physiology.
*a*Journal of the Anthropological Institute of Great Britain.
*a*Journal of Manchester Geographical Society.
*a*Journal of the Royal Institute of British Architects.
Journal of the Royal Microscopical Society.
*a*Journal of the Royal Statistical Society.
*a*Journal of the Scottish Meteorological Society.
*a*Memorias y Revista de la Sociedad Cientifica " Antonio Alzate."
Mind : a Quarterly Review of Psychology and Philosophy.
*a*Proceedings of the American Philosophical Society.
Quarterly Journal of Economics.
Quarterly Journal of Geological Society.
*a*Quarterly Journal of Royal Meteorological Society.
Quarterly Journal of Pure and Applied Mathematics.
Reliquary and Illustrated Archaeologist.
*a*School of Mines Quarterly.
Scottish Historical Review.
Scientific Roll.

ANNUALLY.

British Journal Photographic Almanac.
Jahres-Bericht Chemischen Technologie.
Journal of the Royal Agricultural Society of England.
*a*Journal de L'Ecole Polytechnique.
Ray Society's Publications.
Palaeontographical Society's Publications.
Philosophical Transactions, Royal Society of London.
Report of the Board of Education.
Statesman's Year Book.

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Summer (May till October, except during the holidays), 9.30 a.m. till 5 p.m., Saturdays, till 1 p.m.

LIST OF MEMBERS

OF THE

Royal Philosophical Society of Glasgow

For 1924-1925.

HONORARY MEMBERS

(Limited to Twenty)

WITH YEAR OF ELECTION.

FOREIGN.

RUDOLPH ALBERT VON KOLLIKER, Wurzburg, - - - - - - - - - 1860
Professor GEORG QUINCKE, Hauptstrasse 47, Friederichsbau, Heidelberg, - - 1890
Professor IVAN PETROVITCH PAVLOV, Wedenskaja, 4, Petrograd, - - - - 1923

AMERICAN AND COLONIAL.

Sir THOMAS MUIR, M.A., LL.D., F.R.S.S., L. and E., Elmcote, Rondebosch, Cape Colony, - - - - - - - - - - - - - - - - - - 1892
5 ARCHIBALD BYRON MACALLUM, M.A., M.B. (Tor.), Th.D. (Johns Hopkins), Sc.D. (Yale), LL.D. (Aberdeen), F.R.S., University of Toronto, 59 St. George Street, Toronto, Canada, - - - - - - - - - - - - - - - 1908

BRITISH.

Sir ARCHIBALD GEIKIE, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Shepherd's Down, Haslemere, Surrey, - - - - - - - - - - - - - - - 1895
Professor EDWARD ALBERT SCHAFER, LL.D., F.R.S., M.R.C.S., University of Edinburgh, - - - - - - - - - - - - - - - - - 1902
Sir WILLIAM CROOKES, D.Sc., F.R.S., 7 Kensington Park Gardens, London, W., 1908
The Right Hon. Sir HERBERT E. MAXWELL, Bart., F.R.S., D.C.L., LL.D., etc., Monreith, Wigtonshire, - - - - - - - - - - - - - - - 1918
10 The EARL OF BALFOUR, K.G., O.M., 4 Carlton Gardens, London, S.W., - - - 1922
Colonel Sir RONALD ROSS, K.C.B., M.D., D.Sc., LL.D., F.R.S., 41 Buckingham Palace Mansions, London, S.W.1, - - - - - - - - - - - - 1923
Sir J. J. THOMSON, O.M., D.Sc., LL.D., F.R.S., Trinity Lodge, Cambridge, - - 1923
Professor HENRY E. ARMSTRONG, Ph.D., LL.D., D.Sc., F.R.S. (Past President of the Chemical Society), 55 Granville Park, Lewsham, London, S.E., - - - 1925
Sir JAMES GEORGE FRAZER, O.M., D.C.L., LL.D., Litt.D., F.R.S., F.B.A., Trinity College, Cambridge, - - - - - - - - - - - - - - - 1925
15 Professor ANDREW GRAY, M.A., D.Sc., LL.D., F.R.S. (Emeritus Professor of Natural Philosophy, University of Glasgow), The University, Glasgow, - - - - 1925

CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

Sir THOMAS E. THORPE, Ph.D., F.R.S., F.R.S.E., Whinfield, Salacombe, South Devon, - - - 1874
WILLIAM MILNE, M.A., B.Sc., F.R.S.E., Uitenhage, Cape Colony, - - - 1894
Sir RICHARD LODGE, M.A., Professor of History in Edinburgh University, - - 1899
ARTHUR SCHUSTER, Ph.D., F.R.S., Yeldall, Twyford, Berks., - - - 1901
5 Sir WILLIAM S. M'CORMICK, M.A., LL.D., The Carnegie Trust Offices, Merchants' Hall, Edinburgh, - - - 1902
JOHN GEORGE BARTHOLOMEW, F.R.S.E., F.R.G.S., Geographical Institute, Park Road, Edinburgh, - - - 1902
JAMES BURGESS, C.I.E., LL.D., F.R.S.E., Hon. A.R.I.B.A., F.R.G.S., 22 Seton Place, Edinburgh, - - - 1902
FREDERICK EMLEY, Literary and Philosophical Society of Newcastle-upon-Tyne, - 1902
Principal JOHN YULE MACKAY, M.D., LL.D., University College, Dundee, - - 1902
10 Professor JOHN MILLAR THOMSON, LL.D., F.R.S., F.I.C., F.C.S., Athenaeum Club, London, - - - 1902
Professor ROBERT WALLACE, F.R.S.E., F.L.S., F.C.S., University of Edinburgh, 1902
Professor G. F. SCOTT-ELLIOT, M.A., B.Sc., F.R.G.S., etc., Drumwhill, Mossdale, - 1918
Professor H. STANLEY ALLEN, M.A., D.Sc., F.R.S.E., Professor of Natural Philosophy, University of St. Andrews, - - - 1924
Major General Sir DAVID BRUCE, K.C.B., D.Sc., F.R.C.P., LL.D., F.R.S., Lister Institute, Chelsea Bridge Road, London, S.W.1, - - - 1924
15 Sir EDWIN RAY LANKESTER, K.C.B., D.Sc., LL.D., F.R.S., 44 Oakley Street, Chelsea, London, S.W.8, - - - 1924
Sir ERNEST RUTHERFORD, F.R.S., Director of the Cavendish Laboratory, University of Cambridge, Newnham Cottage, Queen's Road, Cambridge, - - - 1924
Sir JOSIAH C. STAMP, K.B.E., D.Sc. (London), Tantallon, Park Hill Road, Shortlands, Kent, - - - 1924
Professor FREDERICK SODDY, M.A., F.R.S. (Professor of Inorganic and Physical Chemistry, University of Oxford), 131 Banbury Road, Oxford, - - - 1925
Sir JAMES WALKER, Ph.D., D.Sc., LL.D., F.R.S. (Past President of the Chemical Society), 5 Wester Coates Road, Edinburgh, - - - 1925

ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

a Denotes Life Members.

*a*ADAM, THOMAS, F.S.I., 27 Union Street, 1892
*a*ADAM, WILLIAM, 7 Oakfield Avenue, Hillhead, 1924
ADDIE, F. R., Provan, Dunblane, 1916
AGNEW, ROBERT R., 296 Bath Street, 1911
5 AILSA, The Marquis of, Culzean Castle, Ayrshire, 1920
AIRD, HUGH M., Heathercraigs, Newton Mearns, 1911
ALEXANDER, A. M., 186 St. Vincent Street, Glasgow, 1920
ALEXANDER, The Rev. ARCHIBALD, B.D., M.A., D.D., United Free Manse, Langbank, Renfrewshire, 1920
ALEXANDER, D. M., 10 Highburgh Terrace, Dowanhill, 1887
10 ALEXANDER, GEORGE W., 47 Melville Street, Pollokshields, 1924
ALEXANDER, JAMES, 4 Walmer Terrace, Ibrox, 1924
ALEXANDER, O. A. C., c/o Mowat Bros., 21 Hope Street, Glasgow, 1913
ALEXANDER, WILLIAM, 88 Hyndland Road, Glasgow, 1916
ALLAN, CLAUD A., Kilmahew, Cardross, Dumbartonshire, 1910
15 ALLAN, Dr. GEORGE A., 22 Sandyford Place, Glasgow. 1924
*a*ALLAN, HENRY, 21 Bothwell St., 1900
*a*ALLAN, JAMES B., Ferndean, Crawford Street, Motherwell, 1916
*a*ALLAN, ROBERT S., 15 Woodside Terrace, 1908
ALLISON, Dr. ANDREW, 7 Buckingham Square, Govan, 1912

20 ALLISON, JOSEPH, Jr., C.A., 219 St. Vincent Street, Glasgow,	1922
ANDERSON, A. C., The Homestead, Prestwick, Ayrshire,	1917
*a*ANDERSON, ALEXANDER, C.E., 37 Parkhill Drive, Rutherglen,	1907
ANDERSON, A. HARVIE, Knockderry, Cove,	1910
ANDERSON, ARTHUR R., 8 Westbourne Ter., Glasgow, W.,	1917
25*a*ANDERSON, DAVID H., Cayton Grange, Haswell, Cheshire,	1904
ANDERSON, HUGH, 74 York St,	1913
*a*ANDERSON, Lt. Col. JAMES, C.M.G., D.S.O., "The Elms," Milliken Park, Renfrewshire,	1920
ANDERSON, J. B. MACKENZIE, M.B., 33 Lyndoch Street,	1895
ANDERSON, The Rev. ROBERT C., M.A., 250 Nithsdale Road, Pollokshields, Glasgow,	1920
30*a*ANDERSON, ROBERT LOCKE, 233 St. Vincent Street,	1901
ANDERSON, THOMAS, 21 Cartha Street, Langside,	1922
*a*ANDERSON, WILLIAM, 133 Wellington Street,	1890
ANDERSON, WILLIAM, J.P., 59 Kirklee Road, Kelvinside,	1909
ANDERSON, W. BOYD, 137 St. Vincent Street,	1908
35 ANDREW, D. C., "Davaar," Ledcameroch Road, Bearsden, near Glasgow,	1920
*a*ANDREW, JAMES, LL.D., 160 West George Street.	1900
ANGUS, JOHN G. S., L.D.S., 16 Newton Place,	1912
*a*ANNAN, J. CRAIG, 518 Sauchiehall Street,	1888
ARCHIBALD, HENRY, Gowrie Villa, Uddingston,	1920
40 ARMOUR, WILLIAM, 153 Queen Street,	1918
ARNEIL, ALLAN, Craigenrig, Stewarton Drive, Cambuslang,	1901
*a*ARNOT, J. L., 204 Bath Street,	1890
*a*ARTHUR, ANDREW, 78 Queen Street,	1902
*a*ARTHUR, JAMES, 78 Queen St.,	1900
45 AUCHINVOLE, STEWART P., St. Leonard's, Kilmacolm.	1917
AULD, WILLIAM, Rockview, Circular Road, Clydebank,	1922
*a*BALFOUR, Sir ROBERT, Bart., 7 Gracechurch St., London, E.C.3,	1920
BALLANTINE, R. H., C.A., 116 Hope Street, Glasgow,	1917
BALLOCH, JOHN B., 1 York Drive, Hyndland, Glasgow,	1920
50 BANNATYNE, DUGALD, C.A., 31 St. Vincent Place,	1907
BARBOUR, WM., M.B., C.M., 3 Edelweiss Terrace, Partick,	1900
BARCLAY, ANDREW, 5 Lorne Terrace, Maryhill,	1917
BARCLAY, JAMES, 2 Thornville Terrace, Hillhead,	1920
*a*BARCLAY, ROBERT F., M.A., LL.B., 21 Park Terrace, Glasgow,	1916
55 BARMAN, HARRY D. D., Braefield, Helensburgh,	1904
BARNET, JOHN, 137 West Regent Street	1901
*a*BARR, ARCHIBALD, D.Sc., LL.D., Emeritus Professor of Civil Engineering and Mechanics in the University of Glasgow, Westerton, of Mugdock, Milngavie, *Hon. Vice President*,	1890
BARR, JAMES, F.S.I., F.F.S., 221 West George Street,	1919
BARR, JAMES C., 67 Great Clyde Street,	1913
60 BARR, PATRICK, 51 Bath Street,	1902
BARR, R. IRWIN, F.S.I., 221 West George Street, Glasgow.	1923
*a*BARR, THOMAS H., Wimborne, Kilmacolm,	1909
BARRETT, H. HAMILTON, M.A., Shawfield Works, Rutherglen,	1913
BARTHOLOMEW, JAMES, Glenorchard, Torrance, near Glasgow,	1920
65 BATHGATE, H. S., 26 Bellgrove Street,	1912
BAUCHOP, J. D., M.A., LL.B., 27 Glencairn Drive, Pollokshields, Glasgow,	1920
BAXTER, EDWARD J., 41 West George Street, Glasgow,	1920
BEATSON, Sir GEORGE T., K.C.B., B.A. (Cantab.), M.D., 7 Woodside Crescent,	1881
*a*BEATTIE, FRANCIS, Dineiddwg, Milngavie,	1920
70 BEAUMONT, FRANK, High School, Elmbank Street,	1904
BECKETT, CHARLES E., M.A., LL.B., 145 St. Vincent Street,	1903
BECKETT, E. G., Ph.D., F.I.C., Gilmerton, Larbert, Stirlingshire,	1919
*a*BEEDLE, PETER D. RIDGE-, 6 Albert Gate, Dowanhill, W.2.	1902
BEGG, DAVID, C.A., 142 St. Vincent Street, Glasgow,	1920
75*a*BELL, Sir HENRY, Bart., Mynthurst, Reigate, Surrey,	1876
BELL, Sir JAMES, Bart., 135 Buchanan Street,	1877
*a*BELL, JOHN J., 2 Buckingham St., Hillhead, Glasgow, W. 2.	1896

*a*BENNETT, Dr. CHARLES, 282 Bath Street, Glasgow, 1919
*a*BENNETT, Professor PETER, *Secretary*, 14 Cecil St., Hillhead, 1900
80 BENNETT, Dr. S. H., 30 Windsor Terrace, off St. George's Road, 1922
BERGIUS, WALTER, 26 Whittinghame Drive, Glasgow, W. 1917
BERGIUS, WILLIAM M., 14 St. Enoch Square, 1907
*a*BERRY, ARTHUR J., 14 Regent Street, Cambridge, 1909
BERRY, R. A., Professor of Chemistry, West of Scotland Agricultural College, 6 Blythswood Square, 1906
85*a*BIGGAR, JOHN M., 180 West George Street, 1918
BIGGART, ANDREW S., 39 Sherbrooke Avenue, Pollokshields, Glasgow, 1920
*a*BIGGART, THOMAS, 105 West George Street, 1900
BINNIE, D. D. LL.B., 183 West George Street 1910
BINNIE, THOMAS, M.A., 3 Park Gate, 1903
90 BISACRE, F. F. P., M.A., B.Sc., 17 Stanhope Street, Glasgow, 1919
*a*BISHOP, A. HENDERSON, Thorntonhall, Lanarkshire, 1896
BLACK, HAROLD J., 88 West Regent Street, Glasgow. 1923
*a*BLACK, WILLIAM DUNN, J.P., The Manor House, Wallington, Surrey, 1901
BLACK, WILLIAM GEORGE, C.B.E., LL.D., Ramoyle, Dowanhill Gardens, Glasgow, 1920
95 BLACKIE, JOHN, 1a Westbourne Gardens, Glasgow, W.2., 1912
*a*BLACKIE, WALTER W., B.Sc., The Hill House, Helensburgh, 1886
BLACKLOCK, D. C. STEWART, 49 Westbourne Gds., Kelvinside, 1924
BLACKWOOD, JAMES, Ladehead, Kirkmuirhill, 1920
*a*BLAIR, DAVID L., Firfield, Golf Road, Clarkston, Glasgow. 1923
100 BLAIR, JAMES B., " Greystones," Kilmacolm, 1920
BONHAM, HERBERT, 21 Randolph Gardens, Partick, 1909
BORLAND, W. A., 102 St. Vincent Street, Glasgow, 1921
*a*BOSTON, ALEXANDER L., 12 Argyle Arcade, 1902
BOTTOMLEY, JAMES T., M.A., LL.D. (Glas.), D.Sc., F.R.S., F.R.S.E., F.C.S., 13 University Gardens, Hillhead, 1880
105 BOWER, F. O., D.Sc., M.A., F.R.S., F.L.S., Emeritus Professor of Botany, University of Glasgow, 1 St. John's Terrace, Hillhead, 1885
BOYD, JAMES, Glenhead, Lenzie, 1905
BOYD, JOHN, 60 Cambridge Drive, Glasgow, W. 1924
BOYD, T. A., Shettleston Ironworks, Glasgow, 1908
BOYD, Dr. WILLIAM E., 17 Sandyford Place, Glasgow, 1919
110*a*BOYNE, JAMES, Duncliffe, Bearsden, 1901
BRAID, GEORGE G., A.M.I.C.E., " Lamancha," 15 Victoria Circus, Glasgow, W., 1920
BRAND, Dr. G. B., 10 Woodside Place, Glasgow, 1920
BRODIE, WILLIAM, B.L., 77 St. Vincent Street, 1902
BROMHEAD, HORATIO K., F.R.I.B.A., I.A., 95 Bath Street, 1901
115 BROWN, A. C., 21 Fernleigh Rd., Merrylee, Glasgow, 1922
BROWN, ADAM GILLISON, 17 Kirklee Road, Kelvinside, 1909
BROWN, E. J. V., 197 Onslow Dr., 1911
*a*BROWN, HUGH, Croftmore, Skelmorlie, 1887
BROWN, J. GRANDISON, 34 Craigpark Drive, 1913
120*a*BROWN, J. HALLY, Craignahullie, Skelmorlie, 1920
*a*BROWN, JOHN, B.Sc., Assoc. M.Inst.C.E., 104 West George Street, Glasgow, 1916
BROWN, JOHN ARTHUR, 8 Blythswood Square, Glasgow, 1912
BROWN, JOHN T., M.A., B.Sc., 13 Randolph Place, Mount Florida, Glasgow, 1921
BROWN, J. T. T., LL.D., Ashfield, Cambuslang, 1902
125 BROWN, KELLOCK, R.B.S., 152a Renfrew Street, 1913
*a*BROWN, NICOL PATON, 22 Belhaven Terrace, 1901
BROWN, ROBERT, S., Jun., Riverbank Works, Pollokshaws, Glasgow, 1922
BROWN, STUART H., Royal Starch Works, Paisley, 1920
BROWN, WILLIAM, C.B.E., J.P., 7 Whittingehame Gardens, 1920
130*a*BROWN, WM. STEVENSON, 67 Washington Street, 1886
BROWNING, DANIEL, 4 Clayton Terrace, Dennistoun, 1913
BROWNING, GEORGE, 5 Alfred Terrace, Great Western Road, 1922

BROWNLEE, ROBERT, 5 Winton Drive, Glasgow, W., 1920
BROWNLIE, JOHN DOUGLAS, M.B., Ch.B., L.D.S., 220 West George Street, 1901
135 BROWNLIE, Rev. WILLIAM, M.A., The Manse, Lenzie, 1920
BRUCE, Sir ROBERT, LL.D., Brisbane House, Bellahouston, Glasgow, *Vice-President*, 1917
BRYCE, THOMAS H., M.A., M.D., Professor of Anatomy in the University of Glasgow, 2 The University, 1908
BRYSON, A. M., 92 Trongate, Glasgow, 1919
*a*BUCHANAN, ANDREW, Dean House, Helensburgh, 1902
140 BUCHANAN, Dr. DONALD, 7 AlbanyDr., Burnside, Rutherglen 1924
*a*BUCHANAN, GEO. DOUGLAS, Nether Kirkton, Neilston, Renfrewshire, 1901
BUCHANAN, HUGH R., LL.B., S.S.C., 172 St. Vincent Street, 1915
BUCHANAN, JAMES, M.A., 12 Hamilton Drive, Maxwell Park, Glasgow, 1918
BUCHANAN ROBERT MACNEIL, M.B., C.M., F.F.P.S.G., St. Helens, Scotstounhill. 1900
145 BUCHANAN, WALTER, Dunclutha, Tollcross, 1909
*a*BUCHANAN, WM., "Allanton," South Erskine Park, Bearsden, 1886
BURNET, FRANK R., Enterkin, Kilmacolm, 1924
BURNET, Sir JOHN JAMES, LL.D., A.R.S.A., F.R.I.B.A., 1 Montague Place, Bedford Square, London, W.C., 1892
BURNETT, The Rev. ANDREW, 7 Seton Terrace, Dennistoun, Glasgow, 1920
150 BURNETT, Rev. GEORGE, Dunvegan, Rutherglen, 1913
BURNS, ALEXANDER, M.A., 8 Marlborough Gardens, Clarkston, Glasgow, 1920
*a*BURR, ROBERT A., M.A., B.Sc., 25 Carlyle Drive, Cardonald, 1904
*a*BURRELL, WM., 54 George Sq., 1900

*a*CAIRD, PATRICK T., Belleaire, Greenock, 1920
155 CAIRNS, A. A., Kimberley, Scotstounhill, 1917
CALDER, GEORGE, B.D., D.Litt. Lecturer on Celtic, University of Glasgow, 4 Oakfield Terrace, Glasgow, W., 1918
*a*CALDWELL, GEORGE B., Scotia Leather Works, Boden Street, 1892
*a*CALDWELL, T. C., M.A., LL.B., 9 Crown Terrace, Dowanhill, Glasgow, 1920
CAMERON, Sir HECTOR C., M.D., Professor of Clinical Surgery, University of Glasgow, 18 Woodside Crescent, 1873
160 CAMERON, WILLIAM, B.Sc., A.R.C.S., Oakley, Bishopbriggs, Glasgow, 1921
CAMPBELL, ALEX., 38 Limeside Avenue, Rutherglen. 1922
*a*CAMPBELL, ARCH., Govan Road 1895
CAMPBELL, Sir ARCHIBALD, Bart., of Succoth, D.L., J.P., Garscube, Glasgow, 1920
CAMPBELL, JAMES MURDOCH, Grantallan, Milngavie, 1901
165 CAMPBELL, JOHN, 49 St. Andrew's Drive, Pollokshields, 1901
*a*CAMPBELL, JOHN FERGUSON, 15 Montgomerie Street, North Kelvinside, 1892
CAMPBELL, JOHN, J.P., 116 Terregles Avenue, Maxwell Park, 1917
*a*CAMPBELL, JOHN R., 135 Buchanan Street, Glasgow. 1923
CAMPBELL, Sir MALCOLM, 18 Gordon Street, 1894
170 *a*CAMPBELL, W. H., Daldorch, Catrine, Ayrshire. 1923
CANT, JAMES, Dunard, Skelmorlie, Ayrshire, 1912
CARGILL, DAVID W. T., 163 Hope Street, Glasgow, 1920
*a*CARGILL, Sir JOHN T., Bart., 175 West George St., Glasgow. 1918
CARISS, ARTHUR F., 47 Stevenson Drive, Shawlands, Glasgow, 1920
175 CARLAW, ALEC LYLE, 10 Somerset Place, Sauchiehall St., 1908
CATHCART, Professor E. P., M.D., D.Sc., F.R.S., The University, Glasgow, 1920
CAVEN, Professor, Royal Technical College, Glasgow, 1923
CHALMERS, A. K., M.D., D.P.H., (Camb.), 4 Grosvenor Terrace, Hillhead, 1892
CHALMERS, MALCOLM, J.P., "Sunnybrae," 14 Dargarvel Avenue, Dumbreck, Glasgow, 1920
180 CHAMBERLIN, G. E., 45 Renfield Street, Glasgow, 1920
CHAPMAN, CECIL, A.I.C., 108 Gala Street, Riddrie, Glasgow, 1921
*a*CHISHOLM, W. H. P., Dental Surgeon, 43 Falkland Mansions, Hyndland, Glasgow 1920

CHRISTIE, GEORGE H., 46 West George Street, Glasgow, 1918
*a*CHRISTIE, HENRY W., 46 West George Street. 1892
185 CHRISTIE, JAMES ROBERTON, O.B.E., M.A., LL.B., K.C., 2 Doune Terrace, Edinburgh, 1903
CHRISTIE, JOHN, Turkey Red Works, Alexandria, Dumbartonshire, 1868
CHRISTIE, Dr. WILLIAM W., 12 Rosslyn Terrace, Glasgow, W., 1922
CHRYSTAL, JAMES, 191 Sauchiehall Street, Glasgow, 1919
CLARK, The Rev. DUGALD, B.D., Springburn Manse, Balgrayhill, 1920
190*a*CLARK, GEORGE, Mokoia, Troon, 1922
CLARK, JOHN, M.A., Bushyhill House, Cambuslang, 1897
*a*CLARK, ROBERT, 21 Bothwell Street, Glasgow, 1916
*a*CLARK, WM., 16 Montgomerie Crescent, W., 1910
CLELAND, Sir CHARLES J., K.B.E., M.V.O., D.L., Bonville, Maryhill, 1918
195 CLELAND, PETER M., 16 Auldgirth Road, Mosspark, Glasgow, 1920
CLEMENT, Sir THOMAS, K.B.E., Barcapel, Newton Mearns, 1920
CLYDE, ALEX. P., 57 Bothwell St. 1917
CLYDE, WALTER P., Netherhall, Lenzie, 1917
COATS, JAMES, M.A., B.L., 145 West George St., Glasgow, 1921
200 COATS, JOHN J., M.A., 27 Woodside Place, 1900
*a*COMBE, JAMES RUSSELL, 10 Camphill Avenue, Langside, 1895
*a*CONNELL, JAMES G., 61 M'Alpine Street, 1900
CONNOR, W. MUIR, L.D.S. (Glas.), 9 Berkeley Terrace, Glasgow, W., 1920
COOPER, DAVID, Daldowie, Langside Road, Newlands, 1916
205 COPELAND, ALBERT E. R., C.A., 90 Mitchell Street, 1920
COULSON, W. ARTHUR, 47 King Street, Mile-end, 1888
COUPER, J. B., 82 Mitchell Street, 1913
COUPER, SINCLAIR, Moore Park Works, Helen Street, Govan, 1896
CRAIG, GEORGE, F.I.C., 95 Bath Street, 1912
210 CRAIG, JAMES S., Randolph Hill, Dunblane, 1913
CRAIG, JOHN, The Moorings, Motherwell, 1925
CRAIG, T. A., C.A., 17 Kersland Terrace, Hillhead, 1886
CRAIG, WILLIAM T., F.R.G.S., 1 Minard Road, Partickhill, Glasgow, W., 1920
CRANSTON, JOHN A., D.Sc., Royal Technical College, Glasgow, 1923
215 CRAWFORD, GEORGE B. C., Southpark, Newlands, Glasgow, 1920
CRAWFORD, JOHN, Southpark, Newlands, Glasgow, 1920
*a*CRAWFORD, R. C., 12 Derby Crescent, Kelvinside, 1902
CREE, H. G., 7 Derby Crescent, 1908
CREE, JOHN S., 2 Grosvenor Crescent, Kelvinside, 1918
220 CRERAR, Bailie JAMES ARROL, Garbhallt, Monreith Road, Newlands, 1924
CROMAR, A. H., M.A., 6 Caird Drive, Partickhill, 1920
CROSBIE, WARREN, B.L., 30 George Square, 1904
CROSHER, WILLIAM, 50 Albert Drive, Pollokshields, 1920
CROWTHER, WM. CHAS., 3 Radcliffe Terrace, Minard Road, Crossmyloof, 1922
225 CRUM, JOHN G., M.A., 34 West George Street, Glasgow, 1920
*a*CRUM, WALTER G., Dalnotter House, Old Kilpatrick, 1895
CRUM, WILLIAM G., Longworth Manor, Farringdon, Berks., 1896
CRUSH, SAMUEL T., Westcombe, Southbrae Drive, Jordanhill, Glasgow, 1920
*a*CUBIE, ADAM, L.D.S. (Glas.), 211 Great Western Road, Glasgow, 1920
230*a*CUMMING, Dr. J. B., 18 Ibrox Terrace, Glasgow, 1920
*a*CUNNINGHAM, JAMES, J.P., 2 Oakley Terrace, Dennistoun, 1912
*a*CURPHEY, WM. SALVADOR, 87 Canfield Gardens, So. Hampstead, London, N.W., 1883
CURRIE, Professor J. D., M.A., M.D., The University, Glasgow, 1924
CUTHBERT, Dr. CHARLES C., 3 Buckingham Terrace, Kelvinside, Glasgow, 1922
235 CUTHBERT, ROSS, 26 Park Circus, Ayr, 1920
CUTHBERT, T. S., 90 Norse Road Scotstoun. 1923
CUTHBERT, WILLIAM, 21 Carlton Place, Glasgow, 1918
CUTHBERTSON, JOHN, M.A., F.E.I.S., 97 Greenhead Street, Glasgow, 1909

*a*DALLAS, Ex-Councillor JOHN, 6 Holyrood Crescent, 1911
240*a*DALY, JAMES, 2 Prince's Gardens, 1898
*a*DALY, Rev. J. FAIRLEY, M.A., B.D., F.R.S.G.S., 17 Park Circus Place, W., 1913
DAVIDSON, DAVID, 7 Bute Mansions, Hillhead, 1905
DEMPSTER, JAMES, 6 Leslie Road, Pollokshields, 1913
DENHOLM, DAVID, 75 Waterloo Street, 1910
245 DEWAR, DAVID, 9 South Park Terrace, Hillhead, 1909
DEWAR, JAS., M.A., F.E.I.S., Schoolhouse, Chryston, 1903
DEY, JOHN F., Glenburn, Blairbeth Road, Rutherglen, 1911
DICKIE, M.B., 8 Waterloo Place, London, S.W.1. 1920
DICKINSON, WILLIAM, 1 Royal Exchange Square, Glasgow, 1920
250 DICKSON, JOHN, Amisfield, Monreith Road, Newlands, 1925
*a*DIXON, WALTER, Derwent, 30 Kelvinside Gardens, 1893
DONALD, GEORGE, M.A., 243 Great Western Road, 1909
DONALD, P. D., Chief Engineer, Clyde Trust, 1923
DONALD, WILLIAM, 19 St. Vincent Place, 1922
255 DONALDSON, HENRY J., B.L., Mackay & Macintosh, 124 St. Vincent Street. 1908
DONALDSON, JAMES R., 186 St. Vincent Street, Glasgow, 1920
*a*DONALDSON, W. BETTS, 14 St. Vincent Place, Glasgow, 1921
DOUGALL, JOHN, M.A., D.Sc., 26 Underwood Street, Langside, 1920
DOUGLAS, CHARLES, M.A., 2 Sardinia Terrace, W2. 1918
260 DOUGLAS, JAMES CARFRAE, Licentiate in Dental Surgery (R.C.S. Eng.), 33 Hamilton Drive, Glasgow, 1920
DOUGLAS, WILLIAM P., 242 West George Street, Glasgow, 1920
DOW, Dr. WILLIAM, Knightswood Hospital, Anniesland, Glasgow, 1921
DOWNIE, THOMAS, 84 Balshagray Avenue, 1886
*a*DREGHORN, DAVID, The Liberal Club, St. George's Place, Buchanan Street, 1896
265*a*DUNCAN, ROBERT, Whitefield Works, Govan, 1890
DUNCANSON, DAVID B., B.Sc. (Lond.), 19 King Edward Road, Jordanhill, 1920
DUNKERLY, Dr. J. S., 16 Wilton Mansions, N. Kelvinside, Glasgow, 1922
*a*DUNLOP, A. THOMSON, "Broxtowe," 27 Newark Drive, Pollokshields, Glasgow, 1920
DUNLOP, JAMES, M.B., C.M., 3 Seton Terrace, Dennistoun, 1924
270 DUNLOP, JOHN, F.E.I.S., 40 Whitehill Street, Dennistoun, Glasgow, 1900
DUNLOP, ROBERT J., Barskimming, Mauchline, 1912
*a*DUNLOP, Sir THOMAS, Bart, 70 Wellington Street, 1902
DUNLOP, THOMAS, 13 Kelvinside Terrace, S., 1913
*a*DUNLOP, THOMAS, Jr., 70 Wellington Street, Glasgow, 1924
275 DUNN, SAMUEL, L.D.S., Amberley, 21 Merrylee Road, Newlands, Glasgow, 1921
DUNN, THOMAS B., 21 Lynedoch Street, Glasgow, 1919
DUNN, WILLIAM, Strathyre, Busby Road, Giffnock, 1924

EADIE, DAVID S., Norham, 7 Sutherland Ave., Maxwell Park, 1920
EASDALE, JAMES, 12 Princes Terrace, Dowanhill, 1918
280 EASTON, D. T., 30 George Square, Glasgow, 1920
EATON, JAMES C., Junr., 208 West George Street, 1922
EATON, JOHN, 208 West George Street, Glasgow, 1922
*a*EDINGTON, GEO. HENRY, M.D., D.Sc., M.R.C.S. (Eng.), F.R.F.P.S.G., 20 Woodside Place 1896
EDMISTON, J. C., M.D., F.F.P.S.G., 24 Wilton Gardens, Kelvinside, N., 1910
285*a*EDMISTON, R., Jr., 7 West Nile Street, Glasgow, 1920
*a*EDWARDS, JOHN, LL.D., F.R.S.E., 4 Great Western Terrace, West, *Hon. Vice President*, 1883
ELLIOTT, JOSEPH J., City Chambers, Glasgow, 1901
ELLIOT, Dr. Wm. M., Ruchill Hospital, Glasgow, 1920
ELLIS, DAVID, D.Sc. (Lond.), Ph.D. (Marburg), Professor of Bacteriology, Royal Technical College, Glasgow, Birchtor, Strathblane Road, Milngavie, 1905

290 ERSKINE, J. E., 140 Hope Street, Glasgow, 1920
ESTERSON, JOSEPH B., C.A., 137 West Regent St., Glasgow, 1920
EWAN, THOMAS, M.Sc., Ph.D., 20 Doune Terrace, Glasgow, N.W., 1901

FAILL, JAMES, 146 West Regent Street, Glasgow. 1924
*a*FAILL, JOHN, 7 Winton Drive, Kelvinside, 1901
295*a*FAIRY, JAMES, "Dysart," 187 Stonelaw Road, Rutherglen, 1920
FALCONER, J. D., M.A., D.Sc., F.R.S.E., 35 St. Leonard's Terrace, Chelsea, London, S.W., 1911
FARMER, W. S., 97 Bath St., 1913
*a*FARQUHAR, JAS. T., 47 Hope Street, 1901
FARQUHAR, WM. R., Mossyde, Kilmacolm, 1892
300 FARQUHARSON, W. H. S., M.A., B.Sc., 24 Clincarthill Road, Rutherglen, 1909
FAWSITT, CHARLES A., Glenfruin, Milton Road, Harpenden, Herts., 1879
*a*FERGUS, FREELAND, M.D., LL.D., F.R.S.E., F.R.F.P.S.G., 14 Newton Place, *Hon. Vice-President.* 1887
*a*FERGUS, OSWALD, D.D.S., L.D.S., F.R.S.E., 14 Newton Place, 1896
FERGUSON, JOHN J., 50 Wellington Street, Glasgow, 1920
305 FERRIE, T. Y., 69 Buchanan Street, Glasgow, 1920
FIELD, RICHARD H., 21 Carmichael Place, Langside, 1921
FINDLAY, JAMES, M.A., 41 West George Street, 1918
FINDLAY, JOHN G., Tour, Kilmaurs, Ayrshire, 1920
FINDLAY, Dr. LEONARD, 3 Clairmont Gardens, Glasgow, W., 1923
310 FISHER, ROBERT, F.C.I.S., 69 Mount Annan Drive, Cathcart, Glasgow, 1920
FLEMING, JOHN, 9 Woodside Crescent, 1910
FLEMING, JOHN T., M.A., 129 Bath Street, 1908
*a*FLETCHER, DONALD C., 5 Kirklee Gardens, Kelvinside, 1909
FORBES, Rev. J. T., M.A., 19 Queen's Gate, Dowanhill, 1913
315 FORMAN, ARTHUR N., 160 Hope Street, Glasgow, 1924
*a*FORMAN, J. GRANT, The Lodge, Douglas Pier, Lochgoil, 1924
FORSTER, A. LINDSAY, 12 Athole Gardens, Glasgow, 1921
FORSYTH, STUART S., Vanduara, 90 Springkell Avenue, Maxwell Park, 1917
FORSYTH, W. G., 8 Gordon Street 1910
320 FOTHERINGHAM, T. B., 2 Teviot Terrace, Kelvinside, N., 1889
*a*FOWLER, JOHN, 4 Gray Street, Sandyford, 1880
FRASER, JAMES B., 5 India Street, 1913
*a*FRASER, ROBERT, 2 Crown Gardens, W.2., 1909
*a*FRASER, WM., F.S.I., 209 St. Vincent Street, 1900
325 FRAZER, The Rev. J. M'N., B.D., 4 Moray Place, Strathbungo, Glasgow, 1920
FRENCH, JAMES A., C.A., 5 Whittingehame Drive, Glasgow, 1920
FRENCH, JAMES WEIR, D.Sc., Friarscrag, 23 Kirklee Road, Kelvinside, Glasgow, 1922
*a*FRENCH, THOMAS, Eaglesmore, Trinity Rise, Tulse Hill, London, S.W., 1897
FREW, GORDON THOMSON, 227 West George Street, 1909
330 FRYERS, ARTHUR JOHN, 22 Bath Street, Largs, 1899
*a*FULLERTON, ROBT., M.D., 24 Newton Place, 1896
FULTON, JAMES, The Glen, Paisley, 1897
FULTON, N. O., St. Edmunds, Milngavie, 1920
FYFE, A. PEDEN, 201 West George Street, 1900
335 FYFE, H. H., 21 West George Street, Glasgow, 1920
FYFE, PETER, The Pines, Hillfoot, Dumbartonshire. 1911
FYFE-JAMIESON, JAMES F., M.A., LL.B. (Cantab), of Ruthven, Meigle, Perthshire. 1917

*a*GAIRDNER, C. D., C.A., 115 St. Vincent Street, 1886
*a*GALBRAITH, JOHN ALEXANDER, 15 St. Vincent Place, Glasgow, 1902
340 GALBRAITH, WALTER M., 7 Eglinton Drive. 1893
*a*GALLOWAY, J. MUIR, O.B.E., Balgray, Kelvinside, Glasgow. 1920
*a*GALLOWAY, THOMAS L., Auchendrane, by Ayr. 1920

GALT, THOMAS, 45 Buchan St., S.S., 1913
GARDINER, Sir F. C., K.B.E., LL.D., 174 West George Street, 1907
345 GARDINER, JAMES, Belleville, Hatfield Drive, Kelvinside, 1908
GARDNER, ALEXANDER, 134 Bath Street, 1906
GARDNER, JOHN, Woodend, Houston, 1913
GARDNER, Rev. MATTHEW, D.D., 22 Queen's Gate, Glasgow, 1913
GARDNER, WILLIAM, 27 Washington Street, Glasgow, 1922
350 *a*GARROW, JAMES R., 30 Vinegard Hill Road, Wimbleton Park, London, S.W.19, 1890
GEMMELL, JOHN, 230 Nithsdale Road, Pollokshields, 1912
GEMMILL, WILLIAM, 6 Windsor Circus, 1903
GENTLES, The Rev. ANDREW M. M.A., 1 York Drive, Glasgow, W., 1920
*a*GERSON, MORRIS, 14 Queen St., 1913
355 GIBB, GEORGE, 705 Shields Road, Glasgow, 1922
*a*GIBSON, CHARLES R., F.R.S.E., Lynton, Mansewood, by Pollokshaws, *President*, 1895
GIBSON, GEO. A., M.A., LL.D., Professor of Mathematics in the University of Glasgow 1909
GIBSON, JAMES, M.A., 5 The University, 1905
GIFFORD, HORACE A., 21 Belmont Street, Glasgow, 1917
360 GILCHRIST, JAMES, St. Ronan's, Lochbrae Dr., Burnside, Rutherglen. 1920
GILLESPIE, ROBERT D., M.D., 47 Carolside Avenue, Clarkston, 1922
*a*GILLIES, WILLIAM, LL.D., 23 University Gardens, *Hon. Vice-President*, 1901
*a*GILLIES, WILLIAM, Jr., LL.B., 204 West George Street, 1919
GIRVAN, JOHN, 77 St. Vincent Street, Glasgow, 1920
365 GLAISTER, JOHN, M.D., F.F.P.S.G., D.P.H. (Camb.), F.R.S.E., F.C.S., &c., Professor of Forensic Medicine and Public Health, University of Glasgow, 3 Newton Place, *Hon. Vice-President*, 1879
*a*GLAISTER, JOSEPH NEWBIGGING, M.B., C.M., 4 Grafton Place, 1900
GLEN, ALEXANDER, M.C., M.D., 26 Drive Road, Govan, 1922
*a*GLEN, JAMES, M.A., 14 Lynedoch Crescent, 1913
*a*GLEN, LAWRENCE, 153 St. Vincent Street, 1900
370 GLENARTHUR, The Right Hon. Lord, 78 Queen Street, Glasgow, 1900
*a*GLENCONNER, The Right Hon. Lord, 34 Queen Anne's Gate, London, S.W.1. 1918
GLOAG, ROBERT, 160 Bath Street, Glasgow, 1920
*a*GORDON, JAMES, Stonebyres, 14 Aytoun Road, Pollokshields, 1901
GORDON, JAMES A., M.A., B.L., C.A., 142 St. Vincent Street, Glasgow, 1919
375 GOUDIE, Professor W. J., Bellevue, 1 Kay Park Terrace, Kilmarnock, 1923
GOURLAY, A. MURRAY, C.A., 7 Windsor Quadrant, Kelvinside, Glasgow. 1923
*a*GOURLAY, CHARLES, B.Sc., F.R.I.B.A., F.S.A. (Scot.), Professor of Architecture, Glasgow Technical College, Coniston, Craigdhu Road, Milngavie. 1900
GRACIE, Sir ALEXANDER, K.B.E., M.V.O., 9 Montgomerie Crescent, Glasgow, 1922
GRAHAM, JAMES, B.L., 198 West George Street, Glasgow, 1918
380 GRAHAM, JAMES, 141 Bath Street, 1920
GRAHAM, JOHN, B.Sc., F.R.F.P.S.G., 351 Renfrew St., Glasgow, 1920
*a*GRAHAM, Sir ROBERT, 108 Eglinton Street, 1888
*a*GRAHAM, WILLIAM, B.L., Crosbie, West Kilbride, 1885
GRAHAM, WILLIAM, 3 Oakfield Avenue, Hillhead, 1913
385 GRAHAM, WM. EDWARD AULD, 86 St. Vincent Street, 1900
*a*GRAHAM, WILLIAM, Jr., 3 Oakfield Avenue, Glasgow, 1924
GRANT, IAN M., M.D., 174 Berkeley Street, Glasgow, 1923
*a*GRANT, J. M., 7 Princes Terrace, Glasgow, W., 1916
GRANT, Rev. JAMES BELL, B.D., 3 Albany Street, N. Kelvinside, 1903
390 GRAY, ALBERT A., M.D., 4 Clairmont Gardens, 1903
GRAY, JAMES G., D.Sc., Professor of Applied Physics in the University of Glasgow, 1909
*a*GRAY, THOMAS, D.Sc., Ph.D., LL.D., F.I.C., F.C.S., Professor of Technical Chemistry, Glasgow Technical College, 1904

GREENHORNE, WM., M.A., 23 Annfield Road, Partickhill, 1911
GREENLEES, R. C., Corryville, Paisley, 1922
395 GREENLEES, THOMAS, Jr., Newark, Paisley, 1918
GREENLEES, THOMAS, Ter., Newark, Paisley, 1922
*a*GREGORY, Professor J. W., D.Sc., F.R.S., Glasgow University, 1904
GREGORY, W. M., B.Sc. 70 Kintore Road, Newlands, Glasgow. 1923
GREIG, JOHN, 30 George Square, Glasgow, 1920
400 GREIG, ROBERT C., C.A., Capelrig, Newton Mearns, 1923
*a*GRIERSON, JOHN M., 6 Woodside Place, 1912

HAGUE, B., M.Sc., A.M.I.E.E., 13 Ruthven Street, Hillhead, 1925
HAMILTON, ANDREW, 5 Gilmour Street, Paisley, 1920
HAMILTON, ARCHIBALD, Dunara, Campsie, and 131 West Regent Street, 1918
405 HAMILTON, Col. DAVID, 9 Princes Gardens, Glasgow, W., 1918
*a*HAMILTON, JOHN, F.R.I.B.A., I.A., 112 Bath Street, 1885
HARDIE, WILLIAM, 69 Montgomerie St., Kelvinside, Glasgow, 1920
HARPER, DAVID, Gogovale, Largs, 1920
HARRISON ,PERCY C., 40 Cochrane Street, Glasgow, 1924
410 HAWKINS, S. H., 170 Hope Street, Glasgow, 1923
HAY, DAVID ALLAN, 105 St. Vincent Street, Glasgow, 1919
*a*HAY, RALPH S., 184 Stanley Street, Kinning Park, 1920
HEADRICK, ROBERT, Carrickarden, Bearsden, 1920
HEDDERWICK, ALEX. W. H., 79 St. George, Place, Glasgow, 1924
415 HEDDLE, ERIC W. M., M.C., M.A., B.Sc., 1 Lochee Road, Dundee, 1923
*a*HENDERSON, ANDREW, 15 Cadogan Street, 1906
*a*HENDERSON, A. P., Orchard Mains, Tonbridge, Kent, 1880
HENDERSON, GEO. G., M.A., D.Sc., LL.D., F.R.S., F.I.C., F.C.S., Professor of Chemistry, The University, Glasgow, 1883
HENDERSON, JOHN, M.D., 6 Newton Place, Glasgow, 1924
420 HENDERSON, JOHN, Glen Tower, Kelvinside, 1912
HENDERSON, THOMAS, 5 Belmont Crescent, 1917
HENDERSON, WALTER, M.A., LL.B., 116 West Regent Street, 1912
HENDERSON, WILLIAM, 14 St. Vincent Place, Glasgow, 1921
HENDRY, JAMES, 10 Binnie Place, Glasgow, 1916
425 HENDRY, Dr. JAMES, M.B.E., M.A., B.Sc., 4 Clifton Place, Glasgow, W., 1920
HENDRY, MALCOLM A., 1 Broompark Circus, Dennistoun, 1916
HENDRY, Brigadier General P. W., C.B., 71 Queen Street, Glasgow, 1920
HENDRY, ROBERT, F.S.I., 207 Hope Street, Glasgow, 1922
HEWAT, GOVAN, 114 West George Street, 1912
430*a*HIGHGATE, DAVID, Blairmore, Argyllshire, 1912
HIRD, NORMAN L., 191 Ingram Street, Glasgow, 1920
*a*HOEY, DONALD M'COLL, 9 Bute Mansions, Hillhead, Glasgow, 1922
HOEY, SAMUEL, Tighmonadh, Springburn, 1918
HOGG, CHAS., 9 Exchange Sq., Glasgow, 1918
435 HOLLIS, JOHN, Ardenvohr, Kilmacolm. 1922
HORN, JOHN F., Chardon, Albert Drive, Pollokshields, 1916
HORNE, JOSEPH, M.B., C.M., 45 Windsor Terrace, 1900
*a*HOULDSWORTH, WM. THOS., Clerk in Holy Orders, 1 Mansfield Street, Portland Place, London, W., 1901
HOUSTON, ANDREW, 23 Montgomerie Drive, Kelvinside, 1910
440*a*HOUSTON, R. A., M.A., D.Sc., Ph.D., 45 Kirklee Road, Glasgow 1924
*a*HOWARD, SAMUEL G., M.R.C.V.S., Semper, Victoria Drive, Scotstounhill, 1912
HOWAT, WILLIAM, 74 York St., 1885
HOWDEN, W. H., 195 Scotland Street, Glasgow, 1920
HOWE, Professor G. W. O., D.Sc., Lismore House, Kelvin Drive, Glasgow, N.W., 1923
445 HOWIE, Dr. JOHN L., 66 Newlands Road, Newlands, Glasgow, 1920
HOWIE, ROBERT, 29 Argyle Street, Glasgow, 1916
HUGHES, Rev. ROBERT, Ph.D., B.D., 62 Park Street, Greenheys, Manchester, 1924

HUME, J. HOWDEN, 195 Scotland Street, Glasgow, 1920
*a*HUNTER, ADAM, The Grove, Buchanan Drive, Rutherglen, 1918
450 HUNTER, J. JEFFREY, 89 Bath Street, Glasgow, 1920
*a*HUNTER, Sir JOHN, K.B.E., Dalmarnock Iron Works, 85 Preston Street, Glasgow, 1920
*a*HUNTER, MATTHEW, J.P., Old, Auchendrane, Bearsden, 1916
*a*HUNTER, RICHARD H., Glentyan, Kilbarchan, Renfrewshire, 1900
HUNTER, Professor WALTER K., M.D., D.Sc., 7 Woodside Place, 1899
455*a*HUNTER, WM. S., 70 Robertson Street, 1889
HURRY, ALFRED A., LL.B., The Copse, Kilcreggan, 1919
HUTCHESON, ANDREW, 211 West Campbell Street, 1913
HUTCHISON, JOHN W., 14 Falkland Mansions, 1918
HUTTON, WILLIAM, 35 St. Vincent Place, Glasgow, 1917
460*a*HYSLOP, WILLIAM, of Bank, New Cumnock, 1901

IMRIE, JAMES D., 45 Craigmillar Road, Langside, Glasgow, 1920
INGLIS, DAVID, 5 Park Terrace, Glasgow, 1918
INNES, GILBERT, 16 Kirklee Road, Kelvinside, 1900
INNES, G. J., 8 Queensborough Gardens, Glasgow, W., 1920
465 INSH, GEORGE PRATT, M.A., D.Litt., 35 Camphill Avenue, Glasgow, 1924
*a*INVERCLYDE, The Right Hon. The Lord, Castle Wemyss, 1919
INVERNAIRN, The Right Hon. Lord, of Strathnairn, Parkhead Forge. 1901
*a*IRONS, JOSEPH JONES, Ravenswood, Helensburgh, 1902

JACK, D. T., 3 Cecil Street, Ibrox, Glasgow, 1923
470 JACK, WILLIAM ROBERT, M.D., 16 Woodside Place, 1899
*a*JACKSON, COLIN M., 6 Montague Terrace, Kelvinside, 1912
*a*JACKSON, HAROLD D., Canton Street, Anniesland, 1902
JACKSON, ROBERT, 16 Dixon Avenue, Crosshill, 1902
JEFFREY, WILLIAM, F.R.G.S., F.R.S.A., 1 Gwydyr Mansions, Rochester Gardens, Hove, Sussex, 1920
475 JOHNSTON, Captain J. GILCHRIST, 335 St. Vincent Street, Glasgow, 1920
JOHNSTON, JOHN R., 160 West George Street, Glasgow, 1919
JONES, Dr. HENRY E., 3 Bellahouston Terrace, Ibrox, 1912
JUBB, JOHN, B.L., 124 St. Vincent Street, 1902

KAY, ARTHUR, J.P., F.S.A. (Lond. and Scot.), 11 Regent Terrace, Edinburgh, 1904
480 KAY, THOMAS, 26 West Bothwell Street, Glasgow, 1920
KAYE, EDWARD P., M.Sc. (Manc.), 2 Smith Street, Hillhead, Glasgow, 1921
*a*KELLY, ALEXANDER, 130 Hyde Park Street, 1901
*a*KELLY, A. BROWN, M.D., D.Sc., 26 Blythswood Square, 1908
KEMP, WM., c/o Mrs. Beaver, Greenside, Row, Dumbartonshire, 1898
485*a*KENNEDY, ALEXANDER, Kenmill House, Bothwell, 1902
KENNEDY, Sir ALEXANDER M., J.P., The Fairfield Shipbuilding and Engineering Co., Ltd., Govan, 1920
KENNEDY, Col. ARCH. ARROL, D.S.O., O.B.E., T.D., J.P., 18 Huntly Gardens, Glasgow, 1921
*a*KENNEDY, MOSES HUNTER, 217 West George Street, 1901
*a*KENNEDY, THOMAS W., Carnsalloch, Dumfries, 1921
490*a*KENNEDY, William, Glencreggan, by Glenbarr, Argyll, 1900
KENYON, Dr. RICHARD, Braeside, Balgray Hill, Springburn, 1912
*a*KER, CHARLES, M.A., C.A., 115 St. Vincent Street, 1885
*a*KERR, Dr. DANIEL, 3 Kelvingrove Terrace, Glasgow, 1920
*a*KERR, HENRY H., 3 Mirrlees Drive, Kelvinside. 1913
495 KERR, Dr. J. WISHART, Leeside, Wellshot Drive, Cambuslang, 1917
*a*KERR, Professor JOHN M. MUNRO, M.D., 7 Clairmont Gardens, 1910
KERR, J. GRAHAM, M.A., F.R.S., Professor of Zoology, University of Glasgow, 9 The University, Glasgow, 1904
KIDSTON, J. B., 50 West Regent Street, 1905

*a*KIDSTON, WILLIAM H., 93 West George Street, 1900
500 *a*KIEP, JOHANNES N., 1900
*a*KIEP, WALTER H., M.B., Ch.B., Lismore House, Kelvinside, N., 1910
KING, Professor L. A. L., 48 University Avenue, Glasgow, 1905
KING, WALTER, 95 West George Street, Glasgow, 1920
KINLOCH, JOHN, Dungoyne, Scotstounhill, 1911
505 KIRK, Rev. EDWARD BRUCE, 173 St. Andrew's Road, Pollokshields, 1905
*a*KIRKHOPE, JAMES L., 59 Cambridge Street, 1913
KIRKLAND, GEORGE A. D., 141 West George Street, 1915
*a*KIRKPATRICK, DUNCAN T., 179 West George Street, Glasgow, 1919
KIRKWOOD, CHARLES, F.S.I., 61 West Regent Street, 1908
510 KNIGHT, JAMES, M.A., D.Sc., F.C.S., F.G.S., F.E.I.S., Enterkin, Douglas Gardens, Uddingston, *Hon. Librarian*, 1893
*a*KNOX, DAVID J., 57 St. Vincent Street, 1890
*a*KNOX, Sir JAMES, Place, Kilbirnie, 1917
KNOX, Sheriff JAMES, "Myrtlebank," Airdrie, 1920
KNOX, JOHN, Napiershall School, 1900

515 LAIDLAW, ALEX. M., 70 Mitchell Street, Glasgow, 1920
LAIRD, Dr. WILLIAM, C.B.E., 18 Royal Crescent, Glasgow, W., 1920
LAMBERTON, ANDREW, Blairtummock, Easterhouse, 1904
LAMBERTON, HUGH ALEX., Warnock's Thornton, Thorntonhall, Lanarkshire, 1901
LAMBIE, Dr. JOHN F., 4 Carment Drive, Shawlands, Glasgow, 1920
520 LAMBIE, ROBERT, O.B.E., J.P., 446 Victoria Road, Crosshill, Glasgow, 1901
LAMOND, ROBERT, M.A., LL.B., 107 West Regent Street, 1894
LANDER, Major T. E., Auchtyfardle, Lesmahagow, Lanarkshire, 1912
LANG, GEO., The Wern, Mansewood, by Pollokshaws, 1910
LANG, GILBERT, 180 West Regent Street, 1915
525 LANG, ROBERT, Auldhouse, Pollokshaws, 1910
*a*LANGLANDS, ALEXANDER, 32 Huntly Gardens, 1909
*a*LANGLANDS, E. W., 22 Kennedy Drive, Partick, Glasgow, W., 1902
LANGLANDS, Rev. FRED. D., B.D., Manse of Eastwood, Pollokshaws, 1911
LATTA, JAMES G., Failford, Mauchline, Ayrshire, 1920
530 LATTA, Professor ROBERT, M.A., D.Phil., 4 The University, Glasgow, 1920
*a*LAUDER, JOHN, 92 Bath Street, 1894
LAURIE, WILLIAM KER, 42 Garturk Street, Glasgow, 1917
LAW, ANDREW, 67 Hope Street, 1917
LAWRENCE, ALEXANDER S., 25 University Gardens, 1921
535 LAWSON, THOMAS, 141 Stanmore Road, Mount Florida, 1921
LEAN, DANIEL, 15 Park Terrace, Glasgow, 1918
LEAN, ROBERT, Kirkmay, Prestwick, Ayrshire, 1918
*a*LEASK, HENRY, L. G., M.D., F.R.F.P.S. (Glas.), 70 Dixon Avenue, Crosshill, Glasgow, 1912
LEECHMAN, W. G., 183 West George Street, 1913
540 LEES, WILLIAM, Elmbank House, East Kilbride, 1920
LEGGAT, W. G., Bank of Scotland, 2 St. Vincent Place, 1916
LEVY, REGINALD H., 400 Great Western Road, Glasgow, 1920
*a*LINDSAY, ARCHD. M., M.A., 141 Bath Street, 1872
*a*LINDSAY, JOHN, Dovecot House, Auchtermuchty, 1902
545 LINDSAY, JOHN, M.A., M.D., 18 Burnbank Terrace, 1919
LINDSAY, MATTHEW, F.C.I., National Provident Institution, 65 Renfield Street, Glasgow, 1920
LIPTON, Sir THOMAS J., Bart., K.C.V.O., Grand Officer of the Crown of Italy, Osidge, Southgate, Middlesex, 1905
LITTLEJOHN, WILLIAM D., 201 West George Street, Glasgow, 1920
LIVINGSTONE, MALCOLM, 60 Glencairn Drive, Pollokshields, 1913
550 LIVINGSTONE, WILLIAM, 11 Westfield Street, Crossmyloof, Glasgow, 1920
LOCKHART, DAVID B., Victoria Pottery, Pollokshaws, Glasgow, 1921
LOCKHART, J. T., Victoria Pottery, Pollokshaws, 1919
LOGIE, JOHN, Kersiebank, Cambuslang, 1919

LONGWILL, JOHN R., 68 Virginia Street, 1913
555*a*LOW, ISAAC, 60 Weaver Street, 1898
LOWE, THEODORE D., LL.B., 302 Buchanan Street, 1918
LUCAS, JAMES, M.A., 10 Huntly Terrace, Shettleston, 1917
*a*LUMSDEN, HARRY, M.A., LL.B., 105 West George Street, 1900
*a*LUKE, A. M., Headswood House, Denny, Stirlingshire, 1920

560 M'ADAM, ALEXANDER, 22 Princes Street, Pollokshields, Glasgow, 1920
M'ADAM, DAVID, M.A. (Glas.), B.Sc. (Lond.), 22 Princes Street, Pollokshields, Glasgow, 1920
MACALISTER, Sir DONALD, Bart. K.C.B., LL.D., D.C.L., M.D., Sc.D., Ph.D., F.R.S.E., Principal's House, University, Glasgow, 1918
*a*M'ANDREW, H., 32 Clifford St., Ibrox, 1920
M'AUSLAND, WM. F., 102 Hope St. 1903
565 MACBRAYNE, D. H., 19 Woodlands Terrace, Glasgow, 1920
M'BRIDE, JAMES A., B.Sc., B.A., North Kelvinside School, 1920
M'CALLUM, DUGALD C., Ellangowan, 17 Waverley Park, Shawlands, Glasgow, 1922
MACCALLUM, DUNCAN ,East Cliff, Campbeltown, 1920
*a*M'CALLUM, HUGH, M.A., 7 Bute Mansions, Hillhead, 1902
570 M'CALLUM, JAMES A., LL.B., 15 West George Street, 1910
*a*M'CALLUM, ROBERT, Jr., 69 Union Street, 1891
M'CALMAN, GEORGE, 150 Hope Street, Glasgow, 1905
*a*M'CLELLAND, ANDREW SIMPSON, C.A., 115 St. Vincent Street, 1884
M'CONNACHIE, JOHN, 204 West George Street, 1905
575*a*M'COSH, ANDREW K., Rochsoles, Airdrie, Lanarkshire, 1920
*a*M'COWAN, DAVID, Jr., 9 Park Circus Place, 1898
M'CRACKEN, JAMES, 5 Bowmont Terrace, Kelvinside, 1889
M'CRAE, ALEXANDER, 48 West Regent Street, Glasgow, 1918
MACRAE, Dr. FARQUHAR, 3 Park Circus Place, Glasgow, W., 1918
580 MACRAE, FARQUHAR, M.A., B.Sc., 1 Sharrocks Street, Ibrox, Glasgow. 1923

M'CULLOCH, Rev. JAMES D., 272 St. Vincent Street, 1913
M'CULLOCH, NORMAN G., 87 M'Neil Street, Glasgow, 1922
M'CUTCHEON, Dr. J. G., 14 Belmont Street, 1921
MACDIARMID, A. C., 4 Crown Terrace, Glasgow, W., 1918
585 MACDONALD, Dr. DAVID, 4 Buckingham Terrace, W., 1912
MACDONALD, Dr. JAMES H., Hawkhead Asylum, Paisley, 1912
MACDONALD, JAMES, 84 Fernleigh Road, Newlands, Glasgow, 1923
MACDONALD, THOMAS, L. 9 Colebrooke Terr., Glasgow ,W., 1922
*a*MACDOUGALL, ROBERT, F.S.A.A., F.S.I., 63 Bank Street, Hillhead, 1900
590*a*M'EWAN, ARCHIBALD, 98 Glassford Street, 1920
M'FADYEN, The Rev. Professor JOHN E., B.A. (Oxon.), M.A., D.D., 4 Bruce Road, Pollokshields, Glasgow, 1920
*a*MACFARLANE, GEORGE WM., Benvue, 6 Saint John's Road, Pollokshields, 1911
*a*MACFARLANE, JAMES, LL.D., 2 Montgomerie Crescent, Kelvinside. 1911
*a*MACFARLANE, WALTER, 22 Park Circus, 1885
595 MACFARLANE, Dr. WM. D., Jr., 17 Woodside Crescent, 1906
MACGILCHRIST, The Rev. JOHN, The Manse of Old Aberdeen, Aberdeen. 1920
*a*MACGILL, THOMAS, 14 Montgomerie Crescent, Glasgow, 1917
MACGILLIVRAY, DUNCAN, M.A., 7 Newark Drive Pollokshields, 1906
*a*MACGREGOR, R. D., 137 West George Street, 1900
600 M'GREGOR, WILLIAM, Ardchoille, Airdrie, 1920
MACHARG, A. S., C.A., 115 St. Vincent Street, Glasgow, 1923
M'INNES, WILLIAM, 8 Gordon Street, 1910
M'INTOSH, H. J., British Linen Bank, Whiteinch, 1916
MACKINTOSH, Col. DONALD J., M.B., C.M., LL.D., M.V.O., Western Infirmary, 1894
605 MACINTYRE, JOHN, M.B., C.M., 179 Bath Street, 1895
MACKAY, DANIEL D., Heathmount, Dunblane, 1913

MACKAY, J. D. C., 2 West Regent Street, Glasgow, 1920
aM'KECHNIE, D., 14 Candleriggs, 1900
aM'KECHNIE, JOHN D., 6 Princes Gardens, Dowanhill, Glasgow, 1918
610aM'KECHNIE, Professor WM., S. M.A., LL.B., D.Phil., 12 Oakfield Terrace, Glasgow, W., 1908
M'KELL, WILLIAM M., 7 Whittingehame Drive, 1913
aM'KELLAR, A., 4 Devonshire Gardens, Glasgow, 1919
M'KELLAR, JOHN C., 45 West Nile Street, 1896
aM'KENDRICK, JOHN G., M.D., C.M., LL.D., F.R.S., F.R.S.E., F.R.C.P.E., Emeritus Professor of Physiology in the University of Glasgow, Maxieburn, Stonehaven, *Hon. Vice President*, 1877
615 M'KENDRICK, J. SOUTTAR, M.D., F.R.S.E., 2 Buckingham Terrace, 1900
MACKENZIE, A. O. M., K.C., Sheriff of Lanarkshire, 10 Grosvenor Crescent, Glasgow, W., 1918
MACKENZIE, DAVID J., Deansford, Bishopmill, Elgin. 1916
aMACKENZIE, Dr. IVY, F.R.F.P.S.G., 10 Woodside Terrace, Glasgow, 1920
MACKENZIE, JAMES, LL.D., 150 St. Vincent Street, Glasgow, 1919
620 MACKENZIE, ROBERT, 176 St. Vincent Street, 1905
M'KERROW, W. L., 65 Hamilton Drive, Hillhead, 1908
M'KIE, JOHN, M.B., C.M., 24 Hillside Terrace, 1899
M'KIM, JAMES, Washington Mills, Glasgow, 1920
MACKINLAY, CHARLES A., Thorncliffe, Dowanhill Gardens, 1910
625 MACKINNON, WILLIAM, C.A., 34 West George Street, 1904
aMACLACHLAN, Dr. LEWIS, D.P.H. (Camb.), 14 St. James Terrace, Glasgow, 1920
M'LAUCHLAN, PHILIP C., Maryland, Springkell Avenue, Maxwell Park, Glasgow, 1910
MACLAREN, NORMAN H. W., Ph.D., Cubieshaw, West Kilbride 1922
MACLAREN, ROBERT, Blair Castle, Culross, 1923
630 M'LAURIN, ARCH., Cartside, Milliken Park, 1921
aMACLAURIN, DUNCAN, 26 Ashton Gardens, Glasgow, 1920
M'LAY, WILLIAM, C.A., 75 Stewarton Drive, Cambuslang, 1921
MACLEAN, A.B., Craigpark Works. Flemington Street, Springburn, 1899
MACLEAN, ALEXANDER C., M.A., 9 Torbeck Street, Halfway, Glasgow. 1923
635aM'LEAN, ALLAN, 41 W. George St. 1913
MACLEAN, N. S., C.A., 115 St. Vincent Street, Glasgow, 1920
M'LEAN, ROBERT, Auldfield House, Pollokshaws, 1924
M'LEAN, R. A., Monkton Miln, Ayrshire, 1925
M'LEAN, Dr. SAMUEL, J.P., 13 Armadale Street, Dennistoun, Glasgow, 1920
640aMACLEHOSE, JAMES, M.A., LL.D., The Old Parsonage, Lamington, Lanarkshire, 1882
MACLEISH, HAROLD J., C.A., 116 Hope Street, Glasgow, 1925
M'LELLAN, DUNCAN, Argrey, Barrhead Road, Pollokshaws, 1922
MACLELLAN, GEORGE S., 129 Trongate, 1920
aMACLELLAN, PETER, Glasgow Rubber Works, Maryhill, 1900
645aMACLELLAN, W. TURNER, 129 Trongate, 1920
aMACLELLAN, WM. WALTER, Auchendarroch, Balfron, 1900
aMACLEOD, Sir FREDERICK L. 94 Hope Street, 1901
MACLEOD, NORMAN, C.A., 149 West George Street, 1912
M'LINTOCK, Sir WILLIAM, C.A., 216 West George St., Glasgow, 1920
650 M'MICHAEL, THOMAS, M.A., B.Sc., 17 Highburgh Road, Glasgow, 1901
M'MILLAN, A. LEWIS, M.D., C.M., 6 Lansdowne Crescent, Glasgow. 1879
MACMURRAY, William, 40 Kelvinside Gardens, Glasgow, 1924
M'NAB, ANDREW, Midton House, Howwood, Renfrewshire, 1922
M'NAB, DENIS, Midton House, Howwood, Renfrewshire, 1922
655 MACNAB, ROBERT, 1 Lethington Avenue, 1910
M'NICOL, ROBERT, S., 48 North Hanover Street, Glasgow. 1912
aM'OMISH, ALEXANDER, C.A., 79 West Regent Street, 1911
MACPHAIL, DONALD, M.D., Garturk Cottage, Whifflet, Coatbridge, 1877
MACPHAIL, Dr. D. H., 28 West Princes Street, Glasgow, 1920
660 MACQUAKER, THOMAS, 149 St. Vincent Street, 1902

McQUEEN, The Rev. DAVID, 15 India Street, Glasgow, 1920
*a*M'QUISTAN, D. B., M.A., B.Sc., 29 Viewpark Drive, Rutherglen, 1921
M'TAGGART, D., 59 Stanmore Road, Mount Florida, 1913
MACTAGGART, JOHN A., Kelmscott, Springkell Avenue, 1908
665 M'VIE, GEORGE C., Dunimarle, Brownside Road, Cambuslang, 1917
*a*MACWHANNELL, NINIAN, 11 Jane Street, 1898
M'WHIRTER, ALEXANDER S., 17 Douglas Street, Glasgow, 1920
MAKINS, J VINCENT, Inland Revenue, 30 George Square. 1923
MALCOLM, JOHN, Newhall, Sydenham Road, Dowanhill, 1918
670*a*MALCOLM, WILLIAM, M.A., County Office, Hamilton, 1911
*a*MANN, JAMES, Castlecraig, Dolphinton, Peebleshire, 1900
*a*MANN, Sir JOHN, M.A., C.A., 142 St. Vincent Street, *Hon. Treasurer*, 1885
MANN, LUDOVIC MACLELLAN, 144 St. Vincent Street, 1897
MANSON, Dr. W. HISLOP, 17 Royal Terrace, Glasgow, W., 1920
675 MARKS, SAMUEL, 121 Great Eastern Road, 1913
*a*MARRINER, W. W., Earleseat, Scotstounhill, 1922
*a*MARSHALL, Dr. CAMPBELL S., Dalzean, 123 Cambridge Drive, Kelvinside, North, Glasgow, 1920
MARSHALL, JAMES, 21 Eglinton Drive, 1900
MARSHALL, ROBERT C., of Burntshields, Kilbarchan, Renfrewshire, 1919
680 MARTIN, ANDREW, 154 West Regent Street, 1912
MARTIN, ANDREW, M.A., B.Sc., 1371 Dumbarton Road, Scotstoun, Glasgow, 1922
MARTIN, JAMES F., 63 Brunswick Street, 1895
MARTIN, JOHN, 59 Bath Street, 1901
MARTIN, JOHN H., M.A., M.D., 90 Albert Road, Crosshill, Glasgow, 1923
685 MARTIN, WILLIAM, 63 Brunswick Street, 1903
MARTIN, WILLIAM H., C.A., 147 Bath Street, 1916
MATHIE, GEORGE M., Mayfair, Clincarthill, Rutherglen, 1895
MATHIESON, J. H., 6 Park Circus Place, 1896
*a*MATHIESON, T. O., 1 Park Gardens, 1896
690 MAVOR, ERIC INGRAM, 47 Broad Street, Mile End. 1922
MAVOR, JOHN B., 23 Cranworth Street, Hillhead, Glasgow, 1920
MAVOR, OSBORN HENRY, M.B., F.R.F.P.S.G., 17 Fitzroy Place, 1922
MAVOR, SAMUEL, 9 Crown Gardens, Dowanhill, 1890
MAXWELL, JOHN, 113 St. Vincent Street, Glasgow, 1920
695*a*MAXWELL, Sir JOHN STIRLING, Bart., Pollok House, Pollokshaws, 1905
*a*MECHAN, HENRY, Scotstoun Iron Works, Scotstoun, 1879
MEIKLEREID, DAVID, 4 Hatfield Drive, Kelvinside, 1918
MELLANBY, A. L., D.Sc., Professor of Motive Power Engineering, The Technical College, Glasgow, 1905
MELVILLE, GEORGE A. G., Yorville, 7 Monreith Road, Newlands, Glasgow 1922
700 MENZIES, JAMES R., 44 Athole Gardens, Glasgow, W. 1919
MIDDLETON, Dr. E. L., D.P.H., 31 Randolph Road, Stirling, 1921
MILLER, ALEXANDER, Jr., 34 Rose Street, E., 1899
MILLER, A. M., 292 Langside Road, 1913
MILLER, Dr. ALLAN F., 37 Lansdowne Crescent, Glasgow, 1924
705*a*MILLER, ARCH. RUSSELL, Queensmount, Helensburgh 1884
MILLER, JAS., A,R.S.A. F.R.I.B.A., 15 Blythswood Sq., 1910
MILLER, Professor JOHN M.A., D.Sc., 2 Northbank Terrace, Kelvinside, 1910
*a*MILLER, J. C., 1 Lilybank Terrace, Hillhead 1900
MILLER, J. G., Caroni Sugar Estates (Trinidad) Ltd., 21 Mincing Lane, London, 1919
710 MILLER, ROBERT, F.R.I.B.A., 58 Renfield Street, 1910
MILLER, WILLIAM, Kirkwood, Orchard Street, Motherwell, 1914
*a*MITCHELL, ALEX. BROWN, Gordonbank, Larkhall, 1901
*a*MITCHELL, ALEX. MONCRIEFF, 8 Kew Terrace, Kelvinside, 1903
*a*MITCHELL, ANDREW ACWORTH, M.A., LL.B., 7 Huntly Gardens, 1903

715 MITCHELL, D. K., 160 West George Street, Glasgow, 1919
MITCHELL, E. ROSSLYN, 124 St. Vincent Street, Glasgow, 1920
*a*MITCHELL, GEO. A., M.A., F.R.S.E., 5 West Regent Street, 1883
MITCHELL, J. A. RALSTON, 33 Renfield Street, Glasgow, 1919
MITCHELL, LOUIS A., 40 St. Enoch Square, 1913
720 MITCHELL, ROBERT BURGESS, 75 Waterloo Street, 1922
MOFFAT, JAMES, 116 Hope Street, Glasgow, 1917
MOLLISON, JAMES, 30 Balshagray Avenue, Partick, 1889
MONCUR, Professor G., B.Sc., M.I.C.E., Balgersho, Blairbeth Road, Burnside, 1916
*a*MOND, ROBT. LUDWIG, B.A. (Cantab.), F.R.S.E., Combe Bank, near Sevenoaks, Kent, 1890
725*a*MONRO, T. K., M.A., M.D., F.R.F.P.S.G., Regius Professor of Medicine in the University of Glasgow, 12 Somerset Place, 1897
MONTGOMERIE, JAMES, D.Sc., 342 Argyle Street, Glasgow, 1923
MOODIE, JAMES, M.A., F.E.I.S., Petershill Public School, 1909
MOORE, ALEX., C.A., 209 West George Street. 1918
MOORE, ALEX. GEORGE, M.A., B.Sc., 13 Clairmont Gardens, 1886
730*a*MOORE, ROBERT THOMAS, D.Sc., 13 Clairmont Gardens, 1904
MOORE, Dr. S. J., 27 Buckingham Terrace, W., 1912
MORISON, Professor JOHN L., M.A., Queen's College, Kingston, Canada, 1907
*a*MORTON, GEORGE, Lochgreen, Troon, 1902
*a*MUIR, ALLAN, Ardmay, Newlands Road, Langside, 1881
735 MUIR, ANDREW, 209 St. Vincent Street, Glasgow. 1923
*a*MUIR, JAMES, D.Sc., M.A., Professor of Natural Philosophy, Technical College, Glasgow, 31 Burnbank Gardens, 1904
MUIR, ROBERT, M.D., F.R.C.P.E., Professor of Pathology in Glasgow University, 16 Victoria Crescent, Dowanhill, 1899
*a*MUIRHEAD, ANDW. ERSKINE, The Athenaeum, 1873
MUIRHEAD, JAMES, 3 Lorraine Gardens, 1887
740*a*MUIRHEAD, ROBERT F., M.A., D.Sc., 64 Great George Street, Hillhead, 1879
*a*MUIRHEAD, ROLAND E., Meikle Cloak, Lochwinnoch, 1915
MUNN, DUNCAN, 2 Roseberry Terrace, Glasgow, 1922
*a*MUNRO, DONALD MACKAY, 1901
MUNRO, HUGH, B.Sc., M.I.Mech. 68 Greenlees Road, Cambuslang. 1920
745 MUNRO, JAMES, 3 Bruce Street, Hillhead, Glasgow. 1916
MUNRO, R. A., St. Ronans, Lenzie, 1914
MURDOCH, ALEXANDER, C.A., 94 Hope Street, Glasgow, 1920
*a*MURDOCH, JAMES, 20 Woodlands Terrace, Glasgow, 1916
MURDOCH, JOHN, 157 West George Street, 1901
750 MURDOCH, R. GRAHAME, 20 Woodlands Terrace, Glasgow, 1924
*a*MURRAY, DAVID, LL.D., 169 West George Street, *Hon. Vice-President*, 1876
*a*MURRAY, JAMES W., 27 West George Street, Glasgow, 1916
MURRAY, Bailie JOHN BRUCE, 24 George Square, 1896
MURRAY, R. A., C.A , 175 West George Street, 1905
755 MURRAY, RICHARD, M.A., 1 Partickhill Road, Glasgow, 1922

*a*NAISMITH, WILLIAM W., C.A., 57 Hamilton Drive, Hillhead, 1907
NAPIER, H. A., South Park, Giffnock, 1916
NAPIER, ROBT. GRAHAM, C.A., 121 St. Vincent St., Glasgow 1922
NEILL, HUGH, 87 Union Street, 1912
760 NEILL, W. GARDNER, M.B., Ch.B., 4 Belgrave Terrace, Glasgow, W., 1916
NEILSON, JAMES WILSON, 198 West George Street, 1909
*a*NEILSON, JOHN, Mollance, Castle-Douglas, 1900
*a*NEILSON, WALTER, Ewenfield, Ayr, 1900
NESS, JAMES, M.A., LL.B., 115 Wellington Street, 1904
765 NESS, Professor R. BARCLAY, M.A., M.B., 19 Woodside Place, 1902
NEWLANDS, GEORGE F., 5 Saltoun Gardens, Glasgow, 1920
*a*NEWLANDS, The Right Hon. Lord LL.D. Mauldslie Castle, Carluke, 1918
*a*NICHOLSON, P. BUCHANAN, 63 Albert Drive, Pollokshields, Glasgow, 1920

NICOL, RODERICK M., M.A., LL.B., 116 West Regent Street, Glasgow, 1920
770*a*NICOLSON, JAMES N., Towerwood, Newton Mearns, 1920
NICOLSON, W. B., 166a Bath St, 1906
*a*NIMMO, Sir ADAM, M.A., 7 Great Western Terrace, Glasgow, W., 1917
*a*NIMMO, JOHN D., c/o Walter Duncan & Co., 149 Leadenhall Street, London, E.C.3, 1912
NISBET, GEORGE, 109 Hope Street, Glasgow. 1913
775*a*NISBET, JOHN, 48 Kersland Street, Hillhead, 1905
NISBET, THOMAS, M.A., 5 Hampden Terrace, Mount Florida, 1910
NIVEN, WILLIAM G., 11 Derby Crescent, Kelvinside, N.. Glasgow, 1920
NOBLE, Dr. JAMES MASON, F.R.F.P.S.G., L.D.S., 4 Woodside Crescent, Glasgow, W., 1920

ORMOND, WILLIAM, 8 Eton Terrace, Hillhead, 1913
780*a*OSBORNE, HUGH, 4 Kew Terrace, 1899
*a*OSWALD, Dr. LANDEL ROSE, 1902
OSWALD W. DUNSMORE, L.D.S., 481 Victoria Road, Crosshill, Glasgow, 1920

PARKER, JAMES H., B.L., C.A., 156 St. Vincent Street, 1900
PARKER, JOHN, Parkview, Mill Road, Yoker, 1919
785 PARKER, Dr. W. A., Glasgow District Asylum, Gartloch, 1908
PARRY, ROBERT HENRY, F.R.C.S.E., 25 Blythswood Sq., 1900
PATERSON, J. D., 8 Clairmont Gardens, Glasgow, 1920
PATTERSON, Professor T. S., Ph.D., D.Sc., 10 Oakfield Terr., Hillhead, 1909
PATIENCE, ALEXANDER, 140 London Street, Glasgow. 1924
790 PATON, Professor D. NOEL, M.D., B.Sc., F.R.S., F.R.C.P.E., 4 University Gardens, 1908
*a*PATON, R. D., 104 Belgrove Street, Glasgow. 1923
PATRICK, JOHN, M.B., C.M., F.R.C.S. (Edin.), Surgeon, 5 Newton Place, Glasgow, W. 1924
PATRICK, JOSEPH, M.A., C.A., 247 West George Street, 1893
PATTON, DONALD, M.A., B.Sc., 9 Thornwood Gardens, Broomhill, 1923

795 PAUL, JAMES S., 81 St. Vincent Street, 1920
PAUL, MATTHEW, Kirkton, Dumbarton, 1920
PEACOCK, GEORGE L., 111 Union Street, Glasgow, 1924
*a*PEEBLES, ARCHIBALD, "Ashdene," 5 St. Andrew's Drive, Pollokshields, 1920
PERRY, DAVID, 1 Albert Drive, Pollokshields, 1909
800 PETRIE, JOHN W., 9 Crosbie Street, Maryhill, 1900
PETTIGREW, Sir ANDREW H., 7 University Gardens, Glasgow. 1902
PHILLIPS, Rev. E. P., 40 Kelvingrove Street, W., 1912
PHILLIPS, ROBERT, 8 Forth Street, Pollokshields, Glasgow, 1923
*a*PICKEN, DAVID KENNEDY, M.A., The Master's Lodge, Ormond College, University of Melbourne, Victoria, 1903
805 PINKTERTON, J. CASSELS, B.L., 40 Cochrane Street, Glasgow, 1924
PINKERTON, PETER, M.A., D.Sc., Rector, High School, Elmbank Street, 1914
PITT, S. A., City Librarian, Mitchell Library, North Street, Glasgow, 1918
POLLOCK, JAMES MAITLAND, 14 Wilton Mansions, Kelvinside, N., Glasgow, 1918
POLLOCK, JAMES M., M.A., 20 Balmoral Drive, Cambuslang. 1923
810*a*POLLOCK, W. B., INGLIS, M.D., F.R.F.P.S.G., 21 Woodside Place, Glasgow, 1918
POLLOK, ROBERT, " Belgrano," Bishopton, Renfrewshire, 1920
POOLE, GEORGE, A.C.I.S., 243 Mosspark Drive, Mosspark, Glasgow, 1920
POOLEY, JOHN S., Eblana, Glenburn Road, W., Bearsden, 1910
PRENTICE, THOMAS, 175 West George Street, Glasgow, 1919
815 PRICE, FRANK G., 520 Anniesland Road, Scotstounhill, 1917
PRIMROSE, EDWARD J., M.D., B.Sc., 8 Royal Crescent, West, 1920

RAIT, Professor ROBERT S., M.A., 31 Lilybank Gardens, 1914
*a*RAMSEY, ROBERT, Jr., 14 Park Terrace, 1898
RANKIN, JOHN, 138 West Regent Street, Glasgow, 1920

820 RANKINE, DAVID, 41 Viewpark Drive, Rutherglen, 1921
READMAN, W. A., 24 Hamilton Drive, Glasgow, 1921
*a*REID, ANDREW THOMSON, Auchterarder House, Auchterarder, Perthshire, 1900
REID, DAVID, Bonview, Busby, 1887
*a*REID, The Right Rev. EDWARD T. S., D.D., M.A., F.S.A. Scot., "Ravelston," 994 Great Western Road, Glasgow. 1920
825*a*REID, Sir HUGH, Bart., LL.D., C.B.E., Belmont, Springburn, 1880
REID, HUGH Y., 209 Main Street, Shettleston, 1912
REID, JAMES M., 172 St. Vincent Street, Glasgow, 1920
REID, JAMES, 24 Ashton Gardens, Glasgow, W., 1919
*a*REID, Sir John, 7 Park Terrace, Glasgow, 1918
830 REID, JOHN W., 88 St. Vincent Street, Glasgow, 1922
*a*REID, NICHOLAS M'WHIRTER, 7 Oakley Terrace, Dennistoun, 1901
REID, PETER, F.H.A.S., 38 Sherbrooke Avenue, 1912
*a*REID, WALTER M. N., 15 Moray Place, Edinburgh, 1904
*a*REID, WILLIAM L., M.D., 11 Fitzroy Place, 1882
835*a*RENNIE, JOHN, Wellcroft, Helensburgh, 1901
RICHARD, Dr. WILLIAM J., M.A., Merryflats, Govan, 1920
RICHMOND, DAVID A., C.A., 24 George Square, 1912
*a*RICHMOND, JOHN RITCHIE, Westpark, 14 Hamilton Drive, Pollokshields, 1912
RICHMOND, T. G., B.Sc., Eglinton Foundry, Glasgow, 1923
840 RIDDELL, JOHN, 13 Huntly Terrace, Shettleston, 1913
RINTOUL, PETER, C.A., Kildowan, Dowanhill 1910
RINTOUL, WM., F.I.C. Lauriston, Ardrossan, Ayrshire, 1916
RISK, RALPH, 208 St. Vincent Street, Glasgow, 1921
RITCHIE, WILLIAM, 137 Stockwell Street, Glasgow, 1912
845*a*RITCHIE, WILLIAM TOD, 18 Royal Terrace, W. 1909
*a*ROBERTON, WILLIAM, 252 Sauchiehall Street, Glasgow, 1899
ROBERTSON, COLIN F. F., M.A., LL.B., 132 West Regent Street, Glasgow 1922
ROBERTSON, H. D.. Kilnholm, 3 Merrylee Road, Newlands, 1920
*a*ROBERTSON, HENRY TOD, Meadowbank, Airdrie, 1901
850 ROBERTSON, J. M'GREGOR, M.A., M.B., C.M., 26 Buckingham Terrace, Hillhead, 1881
ROBERTSON, JAS. M., Annfield Mansewood, Pollokshaws, 1910
ROBERTSON, JOHN FINDLAY, 201 Bath Street, Glasgow, 1920
*a*ROBERTSON, JOHN M., 2 University Gardens, Glasgow, 1920
ROBERTSON, PAGE, M.B., C.M., 491 Cathedral Street, 1919
855*a*ROBERTSON, ROBERT, B.Sc., M.Inst. C.E., M.I.E.E., etc., Carnbooth, Carmunnock, Lanarkshire. 1900
ROBERTSON, ROBERT F., 46 Leven Street, Pollokshields, 1917
ROBERTSON, WILLIAM, 18 Highburgh Road, Dowanhill, Glasgow, 1918
*a*ROBERTSON, WILLIAM F., 7 Marlborough Terrace, Kelvinside, 1920
ROBINSON, ROBERT, 54 Balshagray Av., Partick, Glasgow 1920
860 RODERICK H. H., 12 Battlefield Avenue, Langside, Glasgow 1918
ROEMMELE, C. H., 34 Kelvinside Gardens, 1900
*a*RODGER, JAMES G., 1 Clairmont Gardens, 1912
ROGERS, JOHN, Nobel House, Stevenston, Ayrshire, 1909
*a*ROGERS, JOHN C., South Park, Cove, 1888
865*a*ROSE, JAMES A. 38 Montgomerie Drive, Kelvinside, 1907
ROSS, JOHN JOHNSTON, M.A., B.A., 7 Dundonald Road, Glasgow, W. 1924
ROSS, JOHN MUNN, C.A., 113 St. Vincent Street, Glasgow, 1894
*a*ROTTENBURG, PAUL, LL.D., 55 West Regent Street, 1872
ROXBURGH, Colonel J. A., 69 Buchanan Street, 1913
870 ROXBURGH, R. W., M.A., LL.B., Myrtle Bank, Helensburgh. 1923
RUDD, J. A., 2 Northpark Terrace, Hillhead, 1910
RULE, ROBERT, 7 Montgomerie Crescent, Glasgow, 1920
RUSSELL, ROBERT, M.E., Coltness Iron Co., Ltd., Newmains, Lanarkshire, 1901
RUSSELL, WILLIAM W., M.A., 235 West Princes Street 1906

875 RUTHERFORD, GEORGE, 5 St. John's Terrace, Ann Street, Hillhead, 1920

*a*SAMUEL, Sir JOHN SMITH, K.B.E., F.R.S.E., J.P., Secretary to the Lord Provost of Glasgow, City Chambers, 1901
SAWERS, WILLIAM D., F.I.C., Woodend, Giffnock, 1894
*a*SCLANDERS, DAVID, Nunholm, Dowanhill Gardens, Glasgow, 1916
*a*SCOBIE, Dr. WILLIAM, 689 Shields Road, Glasgow, 1920
880 SCOBIE, WILLIAM, M.A., 1108 Argyle Street, Glasgow. 1924
SCOTT, Rev. A. BOYD, M.C., B.D., 18 Lilybank Gardens, Hillhead, 1920
SCOTT, GEORGE J., Bank of Scotland, The Mound, Edinburgh 1919
SCOTT, JAMES, M.A., M.B., 14 Westbourne Terrace, 1912
SCOTT, JOHN, 249 West George Street, 1892
885 SCOTT, J. S., 31 St. Vincent Place, Glasgow, 1919
SCOTT, Professor W. R., M.A., D.Phil., Litt.D., F.B.H., 8 University Gardens, Glasgow, 1916
SERVICE, ANDREW GRAHAM, Dalgowrie, Lenzie, 1910
*a*SERVICE, G. W., J.P., 175 West George Street, Glasgow, 1916
SERVICE, JOHN, Horsletthill House, Kelvinside, Glasgow, W., 1922
890 SERVICE, R. GIBSON, 17 Royal Exchange Buildings, 1900
*a*SERVICE, WILLIAM, 1 Queen's Gate, London, 1900
SERVICE, WILLIAM, 645 Alexandra Parade, Glasgow. 1922
SEWELL, THOMAS, 7 West George Street, Glasgow, 1920
SHAND, F. J., Auchenibert, Killearn, Stirlingshire, 1903
895*a*SHANKS, J. B., 141 West George Street, Glasgow, 1900
SHARP, JOHN, M.I.Mech.E., 28 Burnbank Gardens, Glasgow, 1924
SHARP, ROBERT C., 53 St. Andrew's Drive, Pollokshields, 1913
*a*SHAW, Sir ARCHIBALD M'INNES, LL.D., Ballochmyle, Mauchline, Ayrshire, 1900
*a*SHUTE, A. E., 4 Holyrood Cres., Glasgow, W., 1919
900 SILLARS, Colonel JOHN A., Thistle Works, Govan, 1919
*a*SIMPSON, J. C., M.D., 9 Marlborough Terrace, Kelvinside, 1896
SINCLAIR, JAMES, B.Sc., Winthorpe Mansewood, Glasgow, 1923
SKINNER, GEORGE F., 17 Queen's Gate, Glasgow, W. 1919
SLATER, WILLIAM, Learigg, 69 Monreith Road, Newlands, Glasgow, 1922
905 SLOAN, D. NORMAN, C.A., 190 West George Street, Glasgow, 1919
*a*SLOAN, R. A. WALKER, Belhaven, Troon, 1911
SMAIL, DAVID, Falkland Bank, Partickhill Road, 1913
SMITH, ALBERT A., 104 West George Street, 1918
*a*SMITH, ANDREW, Miltonlea, Kilmacolm, 1901
910 SMITH, CHARLES RANDOLPH, Robinsfield, by Milngavie, Stirlingshire, 1920
SMITH, D. JOHNSTONE, C.A., 142 St. Vincent Street, 1888
*a*SMITH, DAVID BAIRD, LL.B., LL.D., 205 St. Vincent Street, Glasgow, 1903
SMITH, DONALD V. H., 103 North Hanover Street, 1913
SMITH, GEORGE, Procurator Fiscal, Central Police Chambers, Glasgow, 1919
915*a*SMITH, JAMES MURRAY, 11 Bute Gardens, 1910
SMITH, J. P., J.P., Smithfield, Larbert, 1920
*a*SMITH, LEWIS O., 104 West George Street, 1907
SMITH, R. F., Brenfield, 180 South Brae Drive, Scotstounhill, Glasgow. 1923
SMITH, SIDNEY, Elm House, 7 Ormonde Park, Muirend, Glasgow, 1920
920 SMITH, Professor STANLEY PARKER, D.Sc., Royal Technical College, Glasgow. 1923
SMITH, The Rev. WILLIAM CHALMERS, B.D., 13 Broompark Drive, Glasgow, 1920
SMITH, WILLIAM M., 13 Hamilton Drive, Hillhead, 1913
*a*SMITH, W. B., 34 Newark Drive, Pollokshields, 1895
*a*SMITH, W. ROBERTSON, 8 Windsor Terrace, W., 1902
925 SNODGRASS, WILLIAM, M.A., M.B., C.M., F.F.P.S.G., 11 Victoria Crescent, Dowanhill, 1890
SORLEY, JAMES F.I.C., A.R.T.C., 156 Bath St., Glasgow, 1923
*a*SPEIRS, R. R., Maxholm, Bearsden, 1912

*a*SPENCER, Col. CHARLES L., O.B.E., D.S.O., 5 Great Western Terrace, 1891
*a*SPENCER, J. J., 5 Great Western Terrace, 1895
930 SPENS, JOHN A., LL.D., 169 West George Street. 1879
*a*STEEL, JAMES, M.A., 502 St. Vincent Street, 1901
*a*STEEL, WILLIAM STRANG, Philiphaugh, Selkirk, 1889
STEEN, ROBERT, F.C.I.S., 22 Terregles Avenue, Pollokshields, 1922
*a*STENHOUSE, A. R., 11 Windsor Terrace, Glasgow, 1919
935*a*STEPHEN, FRED. J., M.A., M.I.N.A., Invergare, Row, Helensburgh, 1916
STEVEN J. S., Kindrochet, 42 Langside Road, Newlands, 1913
STEVEN, J. WILSON, 9 Princes Terrace, Dowanhill, Glasgow, 1919
*a*STEVENSON, Sir D. M., Bart., 12 Waterloo Street, 1889
STEVENSON, JAMES A., 14 St. Vincent Place, Glasgow, 1918
940 STEVENSON, JOHN R., 19 Alder Road, Hillpark, by Pollokshaws, 1922
STEVENSON, J. V., M.V.O., C.B.E., Shelson Hoath, Nr. Canterbury, 1902
STEVENSON, THOMAS, Amisfield, Hillpark, Pollokshaws, Glasgow, 1923
*a*STEVENSON, Professor WM. B., D.Litt., University of Glasgow, 1912
STEWART, ALEX., 176 Stonelaw Road, Rutherglen, 1913
945 STEWART, A. W., 55 West Regent Street, Glasgow, 1918
*a*STEWART, JOHN BARBOUR, M.B., 17 Woodside Terrace, Glasgow, W., 1919
STEWART, RALPH R., 25 Athole Gardens, Kelvinside, 1912
*a*STEWART, ROBERTSON BUCHANAN, 146 Argyle Street, 1901
*a*STEWART, R. B., 97 West Regent Street, Glasgow, 1912
950 STEWART, ROBERT F., M.C., A.I.C., The Don Coy. Engineers, 16 South Street, London, E.C.2., 1920
STEWART, R. M., 188 St. Vincent Street, Glasgow, 1916
STEWART, WILLIAM, Rochester, Riverside Road, Newlands, 1916
*a*STOBO, THOMAS, Somerset House, Garelochhead, 1884
STOCKDALE, H. F., LL.D., Clairinch, Upper Helensburgh, 1899
955 STOCKMAN, RALPH, M.D., F.R.S.E., Professor of Materia Medica, The University of Glasgow, 12 Woodside Place, 1897
*a*STRAIN, JAMES M., 6 Marlborough Terrace, Glasgow, W., 1900
*a*STRAIN, JOHN, C.E., Cassilis House, Dalrymple, Maybole, Ayrshire, 1876
STRANG, SAM. F., Tresco, Church Road, Giffnock 1923
STRATHCLYDE, The Right Hon. Lord, K.C., LL.D., P.C., 31 Heriot Row, Edinburgh, 1917
960 STRATHIE, DAVID, C.A., 86 St. Vincent Street, 1895
STROUD, Dr. WILLIAM, Anniesland, Glasgow, 1920
*a*SUTHERLAND, DAVID, Balmaccara Hotel, Lochalsh, 1880
*a*SUTHERLAND, JOHN, Columba Hotel, Oban, 1880
SUTHERLAND, J. R., C.E., 45 John Street, 1884
965 SUTTIE, Dr. D. CAMPBELL, Royal Hospital for Sick Children, Glasgow, 1923
SYME, W. S., M.D. (Edin.), 11 Lynedoch Crescent, Glasgow, 1908
SYMINGTON, JAMES, 156 St. Vincent Street, 1912

*a*TAIT, JAMES R., 79 West Regent Street, Glasgow, 1920
TAIT, PETER, 127 Stockwell Street, Glasgow, 1920
970 TATLOCK, J. DOUGLAS, 33 Montgomerie Street, Kelvinside, N., 1909
*a*TAWSE, JAMES, Homebank, Broughty Ferry, 1912
TAYLOR, JAMES, 143 West Regent Street, 1906
*a*TAYLOR, ROBERT, 91 Bothwell Street, 1920
TAYLOR, WILLIAM, L.D.S., J.P., 223 Hope Street, Glasgow, 1920
975*a*TAYLOR, WILLIAM ROBB, L.D.S., 290 Duke Str., Glasgow, 1920
*a*TEACHER, Professor JOHN H., M.A., M.D., 32 Kingsborough Gardens, Dowanhill, 1898
TELFER, W. H., Whitestripe House, Newmains. 1918
TEMPLE, EDWIN, LL.D., 3 Carlton Terrace, Kelvinside, Glasgow, W., 1923
TEMPLETON, ALEXANDER, 156 Hill St., Garnethill, Glasgow, 1922
980 TENNANT, JAMES, 110 Terregles Avenue, Glasgow, 1920

TEVENDALE, CHARLES R., Craigdhu, Motherwell, 1920
THOM, ROBERT, 14 Windsor Terrace, W., Glasgow, 1919
THOMSON, ALEX., M.I.Mech.E., 9 Kirkwood Street, Ibrox. 1922
THOMSON, Sheriff A. S. D., 996 Gt. Western Road, 1916
985*a*THOMSON, EDWARD J., 6 Windsor Terrace, W., Kelvinside, Glasgow, 1904
THOMSON, GILBERT, M.A., C.E., 164 Bath Street, 1885
THOMSON, The Rev. P. D., M.A., D.D., 6 Hughenden Terrace, Glasgow, W., 1920
THOMSON, WILLIAM A., F.R.I.B.A., 88 Bath Street, Glasgow, 1920
THORNTON, WILLIAM, B.L., 79 West Regent Street, Glasgow, 1920
990 TOD, FREDERICK, 2 Snowdon Place, Stirling, 1920
TODD, GEORGE, Trochrague, Ayrshire, 1912
TROTTER, JAMES P., 54 Union Street, Glasgow, 1920
TROTTER, JOHN, 40 Gordon St., 1899
*a*TULLIS, JOHN, John Street, Bridgeton, 1900
995*a*TURNER, Dr. GEORGE N., 5 Royal Terrace, Glasgow, W., 1920
TURNER, Dr. J. W., 37 St. Mungo Street, Glasgow, 1912
TURPIE, JOHN, 420 Sauchiehall Street, 1896
TWADDLE, WILLIAM, 12 Monteith Row, Glasgow, 1922

*a*URE, COLIN M'G. B.A., A.M.I.C.E., Balvaird, Helensburgh. 1923
1000 URE, WILLIAM P., Balvaird, Helensburgh, 1893
URIE, GEORGE, 381 Pollokshaws Road, Glasgow, 1913

*a*WADDELL, ROBERT DAVIDSON, Rednock, Kelvinside, W., 1901
*a*WALKER, ALEXANDER, F.S.I., 18 Queen's Gate, 1903
*a*WALKER, ARCHIBALD, M.A. (Oxon.), F.I.C., F.C.S., Newark Castle, Ayr, 1885
1005 WALKER, DAVID CAMERON, 119 St. Vincent Street, Glasgow, 1921
WALKER, GEORGE B., I.M., 65 Bath Street, 1912
*a*WALKER, HUGH, M.A., M.B., C.M., 52 Kilmarnock Road, Shawlands, 1903
WALKER, J. CRADOCK, F.S.A.A 170 Hope Street, Glasgow. 1921
WALKER, JAMES, 42 Darnley Avenue, Scotstoun, Glasgow, 1920
1010 WALKER, JAMES K., LL.B., 154 West George Street, Glasgow, 1920
WALKER, ROBERT BRYCE, M.A., LL.B., Thorndene, Auchingramont Road, Hamilton, 1912
*a*WALKER, WILLIAM H., Cardarroch House, Airdrie, 1900
WALKER-LOVE, Dr. THOMAS, Greenbank, Airdrie, 1922
WALLACE, ALEXANDER, 8 Doune Gardens, North Kelvinside, Glasgow, 1920
1015*a*WALLACE, WM., M.A., M.B., C.M., L.D.S., 25 Newton Place, 1888
WALMSLEY, THOMAS A., B.Sc. Newcastle Tar Works, Blaydon on Tyne, 1922
WARD, THOMAS K., 32 Balshagray Avenue, Broomhill, Glasgow 1923
WARDHAUGH, JOHN B., C.A., 149 West Regent Street, 1912
WARR, The Rev. ALFRED E., B.D., 11 Kew Terrace, Glasgow. 1923
1020 WARREN, JOHN A., C.E., 94 Hope Street, 1887
WARREN, TIMOTHY, 45 West George Street, 1912
WATSON, ALEXANDER, C.A., 10 Waverley Park, Shawlands, Glasgow, 1920
WATSON, ARCHIBALD, Jr., 9 Montgomerie Drive, Kelvinside, 1918
WATSON, HAROLD, Greyfriars, Barassie, near Troon, 1901
1025 WATSON, JOHN M., Crownpoint Works, David St., Glasgow, E., 1920
WATSON, Dr. R. MACLEOD, Cartmore, Sinclair Drive, Langside, 1912
*a*WATSON, THOMAS LENNOX, I.A., F.R.I.B.A., 11 Loudon Terrace, 1916
*a*WATSON, WILLIAM W., 9 Montgomerie Drive, Kelvinside, 1899
WATSON, Dr. WILLIAM, 2 Third Avenue, King's Park, Cathcart, 1920
1030*a*WATT, JAMES, LL.D., W. S., Craiglockhart House, Slateford, Midlothian, 1920
WAUGH, The Rev. GEORGE, M.A., B.D., 1 Maitland Avenue, Langside, 1920
WEBSTER, Dr. JOHN F., 19 Royal Crescent, Charing Cross, Glasgow, 1912

WEIR, T. H., M.R.A.S., Rockcliffe, Bowling, 1908
*a*WEIR, The Right Hon. Lord, of Eastwood, *Vice-President*, 1912
1035 *a*WEIR, THOMAS M., 227 St. Vincent Street, Glasgow, 1920
*a*WESTWOOD, Dr. DAVID, J.P., Ashlea House, Partick, 1912
WHITE, Dr. JAMES WILLIAM, 2 Regent Park Square, Glasgow, S., 1920
WHITEHEAD, JOHN, 43 King Street, Pollokshaws, 1922
WHITELAW, ALEX., Gartshore, Kirkintilloch, 1920
1040 WHITSON, ARTHUR, 38 Athole Gardens, Glasgow, W., 1916
WHYTE, ALEXANDER C., 26 Ravenshall Road, Shawlands, 1924
WILKIE, HERBERT E., L.D.S., 337 Bath Street, Glasgow, 1920
WILSON, Dr. ANDREW, 16 Woodside Crescent, 1909
*a*WILSON, ARTHUR, 6 Saltoun Gardens, Glasgow, W., 1918
1045 *a*WILSON, DAVID, M.A., D.Sc., F.C.S., Carbeth, Killearn, 1898
WILSON, F. J., D.Sc., Ph.D., F.I.C., Professor, The Royal Technical College, Glasgow, 1919
WILSON, H. ARNOLD (of Messrs. William Jacks & Co.), 19 St. Vincent Place, 1910
WILSON, Professor H. A., D.Sc., F.R.S., 11 The University, Glasgow, 1924
*a*WILSON, HUGH, 4 Washington Street, Glasgow, 1920
1050 WILSON, JOHN, 81 St. Vincent Street, 1913
*a*WILSON, Sir ROBERT, J.P., Dalsalloch, 18 Aytoun Road, Pollokshields, 1910
WILSON, Sir THOMAS F., 40 St. Vincent Place, 1901
WILSON, THOMAS, O.B.E., J.P., 17 Fotheringay Road, Pollokshields, 1902
WINGATE, GEORGE, C.A., 105 West George Street, Glasgow, 1909
1055 WINGATE, R., Clydesdale Bank, Ltd., Moore Place, Glasgow. 1922
WISHART, GEORGE B., M.A. 88 Mossgiel Road, Newlands, Glasgow, 1923
WITHYCOMBE, GORDON R., 113 York Drive, Hyndland, 1920
*a*WOOD, WILLIAM JAMES, J.P., F.S.A. (Scot.), 46 Queen Square, Regent Park, 1893
WORDIE, WILLIAM, 52 Montgomerie Drive, Glasgow, 1923
1060 *a*WORKMAN, WILLIAM ORR, C.A., 5 Crown Terrace, Glasgow, 1920
WORKMAN, W. S., 12 University Gardens, Glasgow, 1921
*a*WRIGHT J. GRAHAM, 86 St. Vincent Street, Glasgow, 1917
WRIGHT, Dr. JOHN, 1 Seyton Avenue, Langside, Glasgow, 1920
*a*WRIGHT, NORMAN G., 86 St. Vincent Street, Glasgow, 1920
1065 WRIGHT, THOMAS G., 150 St. Vincent Street, Glasgow, 1920
WYLIE, WILLIAM A., 45 Buchanan Street, 1901

YARROW, HAROLD E., Craigend Castle, Milngavie, 1916
YORSTON, ROBERT, 121 West Regent Street, 1913
*a*YOUNG, ALEX., Jr., Hillside, Bridge of Allan, 1910
1070 YOUNG, ARTHUR S. L. (Messrs. James Templeton & Co.), William Street, Glasgow 1922
YOUNG, Dr. BRUCE, 8 Crown Gardens, Dowanhill, 1913
YOUNG, CHARLES, 130 West Regent Street, Glasgow 1920
YOUNG, FRED. H., 21 Kirklee Road, Glasgow, W., 1907
*a*YOUNG, JOHN, M.A., B.Sc., Westleigh, 9 Benting Drive, Troon, 1887
1075 YOUNG, J. GRAHAM, B.Sc., M.I.Mech.E., Trynlaw, Symington, by Kilmarnock, 1920
YUILL, A. W., 9 Fotheringay Road, Pollokshields, Glasgow, 1920

INDEX.